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Stavid Engineering, Inc.
Control S 4798-7

INTERIM DEVELOPMENT REPORT
FOR
RADAR AIR TRAFFIC CONTROL CENTER
DISPLAY SYSTEM

This report covers the period of 20 June 1959 to 20 September 1959

Stavid Engineering, Inc.
Route 22, Plainfield, N. J.

Navy Department, Bureau of Ships, Electronics Division

Contract: NObsr77632
Index No.: NE-010200,ST4

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INTERIM DEVELOPMENT REPORT
FOR
RADAR AIR TRAFFIC CONTROL CENTER
DISPLAY SYSTEM

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Contract: Nobsr77632
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ABSTRACT

This report describes the progress of the equipment design and presents the design plan formulated to accomplish the objectives as set forth in Bureau of Ships Specification SHIPS-R-3259, dated 1 December 1958.

The scan conversion device to be used is the Intec type TMA403X which possesses the resolution and storage capabilities required to meet the Equipment Specification. Design of the scan "write" and "read sweep circuitry has progressed to the sweep deflection amplifiers. Electrical specifications for the scan converter deflection yoke has been finalized and design of the yoke drivers will be initiated.

A Reeves type R601H wide band resolver will be used to derive the resolved radar sweeps. Design of the resolver driver has been completed.

A theoretical analysis of the light producing capability of the Schmidt Projector System utilizing the 5AZP4 has shown that a 30-foot lambert image high-light brightness can be obtained. An analysis of the X-ray radiation problem associated with the 5AZP4 and means of providing adequate protection against the danger of X-ray radiations has also been made. A study of the advantages of a vertical display versus a horizontal display indicated that a vertical PPI display offers a number of significant advantages to a horizontal display of equal size.

1. Part I.

1.1 PURPOSE. - This contract encompasses the design, development, construction and testing of two (2) development models of a Radar Air Traffic Control System. This equipment, in conjunction with compatible short and medium range radar systems, will generate and convert a Plan Position Indicator (PPI) display to a television display by means of a scan conversion tube. The scan conversion tube has the ability to store the PPI radar information for a variable number of television scans, thereby, providing target information storage. The television scan will be applied to a projection tube which will produce a 50" display.

1.2 GENERAL FACTURAL DATA. -

1.2.1 Identification of Personnel. -

Engineers	Hours
A. J. Ross	31
J. J. Shea	187
R. J. Melnick	242
R. Mosolgo	296
R. C. Pegg	6
R. Kavlick	128

Technicians	Hours
W. S. Long	32

1.2.2 Patents. - None.

1.2.3 References. - a. National Bureau of Standards, Handbook 50, X-Ray Protection Design.

1.2.4 Formula. - None.

1.3 DETAIL FACTUAL DATA.

1.3.1 Remote Unit. - The Remote Unit of the Radar Air Traffic Control System must accept range - azimuth or polar radar information in the form of a radar trigger, video information, and bearing synchro data. This information must be stored and then converted to a form suitable for display on a 50 inch horizontal indicator. A simplified block diagram of the circuitry required to perform this conversion is shown in Figure 1.

Design considerations of a 50 inch display system dictate that a rectangular or TV-type sweep be utilized. Since the input information is in polar coordinates, some form of scan conversion is necessary. Several types of commercially available devices offer features which lend themselves to both storage and scan conversion. A discussion of the various conversion techniques is presented below.

1.3.1.1 Scan Converter.- A preliminary survey of scan conversion methods and their attendant difficulties was made to determine the best possible approach to the problem. Several types of scan conversion tubes and their associated circuitry were investigated for maximum resolution and maximum circuit simplicity. Included in the investigation were the following three types capable of providing the required function:

1. R.C.A. type 6896/1855 (Graphechon) - This tube is a double ended, non-viewing, electrostatic charge storage tube composed of a writing section, a reading section and a target. Both the writing and reading beams produce a target current; therefore, some method must be employed to separate these signals. This may be done by time sharing or by employing RF modulation of the reading beam and using a tuned output amplifier. Writing and reading can be conducted at the same time; however, some difficulty is encountered when the read and write beams operate simultaneously at the same point.

2. Raytheon type RK703 - This tube is a double ended, non-viewing storage tube employing magnetic deflection on both the read and write guns. Raytheon utilizes this device in the Pathfinder scan conversion system.

3. Intec TMA403X (Frenchechon) - This tube is a double ended, non-viewing storage tube employing magnetic deflection on the write gun and electrostatic deflection on the read gun. Operation and construction of this device is similiar to that of the Graphechon; however, it does not require RF modulation to sort the write and read gun signals as required with the Graphechon. The TMA403X appears to give better resolution, storage control, and halftone presentation than does the Graphechon. The resolution capability of this tube has been verified by Technical Development Center, C.A.A. to 700 lines-per-diameter, which is adequate for the system requirements. The F.A.A. has purchased several systems utilizing the TMA403X video transformation tube. Stavid personnel visited Idlewild Airport, New York, to observe one such system in operation. The resultant picture appeared to be bright, clear, and free from flicker.

Consideration of the characteristics of these storage devices indicated the Intec TMA403X to be the most promising of the three. All further investigations of the scan conversion circuitry has been predicted upon the use of this video transformation tube.

1.3.1.2 Scan Circuitry. - The basic function of the scan circuitry is to scan the target of the storage tube at a fixed rate with a rectangular sweep. The video output of the tube is amplified, and this signal, in addition to the generated sweep waveforms, is transmitted to the display console.

A monitor will also be provided to allow viewing of the signal being presented at the main display console.

The scan or read portion of the video transformation tube is shown in Figure 2. An electrostatic deflection system is employed which uses a rectangular "TV"-type scan with the horizontal and vertical scan frequencies in synchronism. The horizontal scan frequency is determined by the required line resolution of the system. Other important considerations include fly-back time and frequency response of the sweep generator. The vertical frequency, or frame rate, must be high enough to prevent flicker of the display but low enough so that the horizontal frequency is not excessively high. A rate of 28 frames-per-second was selected as the lowest frequency which would still insure freedom from flicker.

Paragraph 3.4.12 of Ships-R-3259 requires that the display shall have a resolution of at least 700 lines for both short and medium ranges. Allowing 100 lines for vertical retrace gives a total of 800 horizontal lines-per-frame. The horizontal sweep frequency is therefore: number of frames-per-second x number of lines-per-frame = horizontal frequency. Twenty eight (28) frames-per-second x 800 lines-per-frame = 22,400 cps. These frequencies will be derived from a basic master oscillator and divided by the required ratio. The resultant timing waveform will be utilized to derive the blanking waveform and sweeps by means of "operational" integrators. These sweep waveforms will be amplified and applied to a paraphase amplifier to derive push-pull deflection signals for the transformation tube and the monitor. The horizontal and vertical blanking will be mixed and the composite blanking utilized in the video transformation tube, the monitor and the display indicator.

The video output of the transformation tube is passed through a low noise preamplifier, a high gain video amplifier, and a distribution amplifier for use in the main display console.

1.3.1.2.1 Timing Generator. - The timing generator will include a 224-KC crystal-controlled oscillator, the output of which will be amplified and shaped. This waveform will be used as a trigger for a series of magnetron beam switching tubes. These tubes form a ten position stepping device which advances an electron beam sequentially or at random in discrete steps for every negative change as applied alternately to the two switching grids.

The first beam switching tube divides by 10, resulting in a 22.4-kc waveform, which is utilized as the horizontal syncronizing signal. Three successive beam switching tubes, arranged to divide by 10, 10, and 8, respectively, produce the required 28 cps vertical sweep frequency. In order to avoid transmitting the long duration pulse required of the vertical sweep generator, two short duration pulses occurring at the leading and trailing edges of the vertical sync waveform are then applied to a multivibrator in the sweep generator, thereby, recreating the original waveform. A timing generator has been preliminarily designed, which contains the components outlined above.

1.3.1.2.2 Scan Sweep Generator. - The horizontal and vertical sweep waveforms will be derived from the timing waveforms and generated by means of "operational" amplifier integrators. A preliminary schematic of the unit is shown in Figure 3.

An operational amplifier consists of a DC amplifier with a feedback network. The transfer function of such a device is determined by the feedback network if the amplifier forward gain is made large. The purpose of the operational amplifier, as used in this system, is to supply an ultra-linear sawtooth waveform, which has a precise duration and amplitude. The duration is held constant by the sync pulses driving the amplifier.

By clamping the start of the integrated wave, a reference level is obtained. The maximum amplitude to which the sawtooth rises is a direct function of the integrator design. This integrator feedback is an R-C network, which produces a final value equal to:

$$e_o = \frac{1}{RC}\int_0^t e_{in}\,dt$$

It is evident from the above equation, that the final value of voltage, with a fixed input voltage, is dependent only upon the R-C components. By proper choice of components, an accurate voltage time waveform is obtained.

The horizontal and vertical sweep sync waveforms will be combined in a cathode coupled mixer and the composite blanking applied to the transformation tube and monitor. A low impedance distribution amplifier will transmit the sweep voltages to the main display console.

The horizontal and vertical sweep channels are identical except for coupling time constants and the R-C integrator feedback network. The horizontal sweep trigger is shaped in a regenerative amplifier while the vertical trigger is generated by a bistable multivibrator from two (2) sync pulses. These shaped waveforms are limited in a diode clipper to maintain a constant amplitude and applied to the operational integrator. The resultant linear sweep output is amplified in a two stage feedback amplifier. This amplifier serves a twofold purpose in that it provides sufficient sweep output for the sweep drivers, and also presents a low impedance output to the sweep cables. This output is also coupled to a distribution amplifier for transmission at low levels to the display console.

The above described circuitry, illustrated in Figure 3, has been breadboarded and is currently being evaluated and optimized.

1.3.1.2.3 Sweep Amplifier. - The required deflection voltages for both the monitor and the video transformation tube, will be generated in paraphase amplifiers. The push-pull signals will then be direct coupled to their respective deflection plates.

1.3.1.2.4 Monitor Indicator. - A three (3) inch monitor scope will be provided to indicate the video present on the target of the video transformation tube. The main sweep voltages will be amplified in a pair of paraphase amplifiers for monitor deflection. The video amplifier output signal will be further amplified for presentation on the monitor. A block diagram of the monitor circuitry is shown in Figure 4.

1.3.1.2.5 Video Amplifier. - The TMA403X target and collector output signals will be amplified in a low noise video preamplifier. This circuit will use 417A low noise triodes in a cascode connection. This circuit is currently being breadboarded for evaluation and optimumization.

The preamplifier output signal will be further amplified in a high gain broadband video amplifier. The required characteristics of this amplifier are currently being investigated and breadboarding of the unit will commence shortly.

1.3.1.3 Range-Azimuth Circuitry. - The Range-Azimuth or "write" circuitry is primarily concerned with deriving a linear polar sweep as a function of the radar trigger and bearing information. Radar video and map video data will be amplified and mixed with internally generated range ring signals for application to the storage tube, with the result that the signal impressed on the target of the storage device is an accurate representation of the radar display.

The "write" section of the scan converter comprises the following functional subunits: (1) Trigger and Sweep Gate Generator; (2) Sweep Generator; (3) Resolver Driver; (4) Bearing Unit; (5) N-S and E-W Sweep Amplifiers; (6) N-S and E-W Sweep Clamp; (7) N-S and E-W Deflection Amplifiers; (8) Range Rings Generator; (9) Video Amplifier; and (10) High-Voltage and Sweep Failure Protection Circuit. A simplified block diagram of the above circuitry is shown in Figure 5.

1.3.1.3.1 Trigger and Sweep Gate Generator. - A breadboard of this circuitry has been completed and performance tests are being conducted. The preliminary schematic diagram is shown in Figure 6.

The trigger generator accepts the positive-going synchronizing pulse from the associated Radar Equipment and produces an output whose amplitude and pulse characteristics are constant and independent of the input trigger characteristics. The circuitry comprises a self-biased pulse amplifier and regenerative-trigger waveform generator which produces a positive-going waveform with a rise time of approximately 0.2 microseconds and a pulse duration of 60 microseconds. A differentiating network in conjunction with a cut-off trigger amplifier selects the positive edge of the differentiated waveform. Occurrence of this trigger is time coincident with the radar sync trigger and is used to turn on the sweep gate generator.

The sweep gate generator is essentially a one-shot multivibrator driven from a low impedance generator. Duration of the sweep gate is determined by the following factors: (1) The plate voltage available at the plate of the trigger amplifier which determines the magnitude of the initial negative swing on timing capacitor C1; (2) The time constant C1, R1; and (3) The bias level at the grid of the multi.

To generate a sweep gate with a fast leading edge, a gate sharpening circuit is employed which comprises a biased amplifier which has as its plate load, the plate resistor of the sweep gate inverting amplifier. Input to the shaper is the positive edge of the trigger gate generator which occurs at the start of the sweep gate. The small delay encountered in the multivibrator circuit (in the order of 0.1 microseconds) is effectively iliminated at the output by adding this short duration pulse to the beginning of the sweep gate waveform.

To insure that each radar synchronizing trigger initiates the sweep at the correct sweep origin, it is necessary to incorporate circuitry to automatically shorten the sweep gate at high pulse repetition rates and long sweep ranges. This gate shortening circuitry automatically shortens the length of the sweep gate so that the sweep recovery time (interval between the sweep gate and the following trigger pulse) is maintained at approximately 125 microseconds.

The duration of the sweep gate is remotely controlled from the operator's control panel at the display console by means of a nine position range selector switch. Control of the sweep gate is accomplished by varying the d-c supply voltage to the gate generator. Under operating conditions where automatic gate shortening is not required, the d-c supply voltage to the sweep gate generator is controlled solely by the Range Selector. On all sweep ranges for which the sweep gate would become too long to permit a minimum recovery time of 125 microseconds, the d-c voltage generated by the automatic sweep shortening circuit controls the gate duration.

1.3.1.3.2 Sweep Generator. - A Miller Run-Down type sweep generator was breadboarded and performance tests are being conducted. The preliminary schematic is shown in Figure 7.

To control the linearity of the sweep from the sawtooth generator, two feedback paths are used. One is negative feedback capacitively coupled from the output stage to the control grid of the pentode; the other is positive feedback from the plate of the output stage to the junction of the resistors in the clamp. A variable 100 ohm resistor, located in the negative feedback path, is used to adjust the step voltage added to the sweep waveform. This step, appearing at the start of the sweep, is necessary to charge up the distributed capacities in the deflection yoke in order to insure that the sweep on the indicator actually occurs at trigger time. To further hasten the charging of the yoke capacitance, a negative spike is added to the step plus sawtooth waveform. The sweep spike capacitor is adjusted so that the sweep starts as soon as possible after trigger time and then moves linearily during the first few miles of the display.

1.3.1.3.3 Resolver Driver. - The breadboard of this unit has been completed but has not been operating with the associated resolver. This is a three stage feedback amplifier with a closed loop gain of one. The amplifier 3 db corner frequencies are 20 and 250,000 cycles-per-second. Open loop gain is 60 db. The amplifier will drive a Reeves type R601H fully compensated wide band resolver. Inherent linearity of the resolved sweep is specified as better than 0.1 percent. A preliminary schematic of the amplifier is shown in Figure 8.

1.3.1.3.4 Bearing Servo Unit. - The purpose of the bearing unit is to rotate the sweep resolver in synchronism with the antenna of the associated radar. The servo loop will consist of the following components: (1) A 1 and 36-speed synchro control transformer; (2) A servo control network which will switch the two-speed synchro data as a function of the magnitude of the error signal so that the 36-speed data will control the servo for small error signals. A stick-off voltage will insure that the servo nulls at the correct position; (3) A power amplifier with a push-pull output stage transformer coupled to the drive motor. Negative feedback will be incorporated in the amplifier design to provide sufficient damping. A block diagram of the servo unit described above is shown in Figure 5.

Provisions will be incorporated in the bearing unit to automatically detect when the antenna rotation drops below a predetermined minimum speed so as to prevent damage to the scan conversion tube. An interlock circuit will disable the high-voltage supply when the minimum RPM circuit is energized.

1.3.1.3.5 N-S and E-W Sweep Amplifiers. - The N-S and E-W sweep amplifiers will be d-c operational amplifiers which provide the necessary gain, as a function of range, to drive the corresponding deflection amplifier. To automatically extend the sweep in the off-centering mode of operation, an auxiliary sweep gain control is connected to the sum point of the N-S and E-W sweep amplifiers. Off-centering of the display in any direction up to one radius, automatically results in a gain change at the corresponding sweep amplifier which varies the sweep deflection in the proper direction to cover the entire display face.

1.3.1.3.6 N-S and E-W Sweep Clamp. - The N-S and E-W clamp circuit prevents the start of the sweep from shifting with changes of sweep direction, reflection rate, or sweep length. To obtain this condition, the sweep base line must be restored to a fixed potential before the start of each sweep. During the active sweep time the clamp circuit is disabled by the clamp gate waveform which is generated in a bi-stable multivibrator circuit. The interval of the clamp gate is purposely made about 70 microseconds longer than the actual sweep interval to insure that the clamp does not operate until the sweep has recovered to its normal baseline. A one-shot multivibrator is used to provide the 70 microsecond delay. Figure 9 is a schematic of the clamp gate circuitry.

1.3.1.3.7 N-S and E-W Deflection Amplifiers. - The function of the N-S and E-W deflection amplifiers is to mix the off-centering and sweep voltages and to produce deflection yoke currents which are proportional to the sum of these input signals. This will be an operational d-c amplifier to provide maximum linearity and gain stability.

1.3.1.3.8 Range Rings Generator. - The range rings generator supplies a continuous train of uniformly spaced pulses which are displayed as intensity marks or rings on the video display. Spacing between the rings is determined by the Range Ring Miles Switch controlled by the operator at the display console. A preliminary schematic of the circuitry is shown in Figure 10.

To allow sufficient recovery time for all tank circuits in the marker oscillator, it is necessary to generate a range ring gate only during alternate range sweep gates. This is done by generating a gate signal and using this to control the occurrence of the range ring gate. A bi-stable multivibrator, triggered by a pulse occurring at the start of the range sweep gate, produces a square wave output which is positive during alternate trigger intervals. This square wave, or ½ frequency gate, is d-c coupled to a coincidence mixer which has as its other input the range sweep gate. The gated range ring signal acts as an on-off switch for the range rings oscillator. Oscillations continue for one gate intervals at the frequency of the resonant tank circuit selected. A regenerative amplifier follows the oscillator to produce a square wave signal for shaping in the amplifier-clipper circuit.

The range rings generator output, consisting of a series of uniformly spaced negative pulses occurring during alternate sweeps, are fed to the video amplifier. A range rings intensity control, located at the display console, varies the plate voltage of the output stage to control the output amplitude. Disabling of the range ring circuitry is effected by biasing the coincidence gate below cutoff thereby disconnecting the gate signal to the marker oscillator.

1.3.1.3.9 <u>Video Amplifier</u>. - The video amplifier receives normal radar video and map video and combines them with the range rings into a composite video signal of sufficient amplitude to drive the scan conversion tube. The video signal is d-c coupled to the cathode of the conversion tube. A d-c restorer clamps the d-c level at the grid of the output video stage to a level set by the operator's setting of the Sweep Intensity Control. Unblanking of the sweep video during the active sweep is accomplished by feeding the range sweep gate to the control grid of the conversion tube. An automatic intensifier circuit will maintain substantially constant brightness for all sweep speeds and repetition rates without manual adjustment of the intensity controls by the operator. Video gain is not affected by this circuit. The automatic intensifier action will be accomplished essentially in two steps: (1) compensation for different radar prf's will be affected by generating a d-c voltage which varies as a function of frequency. An increase in prf, which would normally increase the brightness of the display, will simultaneously produce a proportional increase in negative bias on the unblanked amplifier. The resulting reduction of the intensifier voltage will prevent any substantial increase in the brightness level; and (2) compensation for range variations will be provided by biasing the unblank amplifier in accordance with the position of the Operator's Range Selector Control. The fast sweep used for the shorter ranges would not normally appear as bright as the slow sweep of the long ranges. To eliminate this, the range selector will control the setting of a potentiometer which will provide the correct bias automatically as the range selector is varied.

1.3.2 Indicator Display Unit. - The functional units required to produce the 50-inch display are shown in Figure 11.

A theoretical evaluation of the light producing capability of the Schmidt Projector System with the 5AZP4 was performed, along with tests of an actual operating system. The results look very encouraging, and it would appear that a 30 foot lambert image highlight brightness is obtainable if optical transmission loss and projection screen meter types have been tested and several appear to have outstanding qualities. A large 50 x 50 inch projection screen, using one of the desirable screen materials, has been purchased along with the necessary light meters; i.e., Weston 756 and 759. Further studies, regarding contract requirements and resolutions will be conducted shortly. A slide transparency of a simulated PPI will be projected upon the large screen and this will temporarily serve to enable study of image brightness and ambient illumination conditions.

Investigation of electroluminescense and image light conversion discloses that these techniques are still in the development stage.

Included in this report is an analysis of the X-ray radiation problem associated with the 5AZP4. Protection against the dangers of X-rays can be accomplished by lead lining the projector barrel.

1.3.2.1 Light Output of a Schmidt Projector with 5AZP4 Kinescope. - The light producing capability of a Schmidt projector with 5AZP4 kinescope was studied, both from an empirical and theoretical standpoint. It was found that the light output of the actual operating system is about 200 lumens. For a 50 inch diameter picture this is equivalent to 14.5 foot-candles of incident light and was so measured with a Weston #756 foot-candle meter. A comparison measurement made with the Weston #759 foot-lambert meter shows this to be equivalent to a brightness level of over 60 foot-lamberts. With usual screen losses this brightness may be reduced to about half that value. Thus, 30 foot-lamberts may be available as the brightness viewing level. This system has a numerical aperture of about .75 which is somewhat degraded by the occulting of the kinescope. The 5AZP4 is operated at the rather high ultor levels of 39,000 volts and 400 microamperes.

The light output is theoretically demonstrated as follows: For a 50 inch diameter image, the throw distance physically measured from the projector corrector plate is 73 inches. Since the spherical mirror is approximately 11 inches behind the corrector plate, the total image converging distance is about 84 inches. Therefore, with a mirror diameter of 14 inches, the image semi-convergence angle, Θ, is:

$$\tan \Theta = \frac{7}{84} = .0835 \qquad \Theta = 4.77^{\circ}$$

$$\text{and } \sin \Theta = .0831$$

Image illuminance is given by the following expression:

$$E = \pi B \sin^2 \theta$$

Where:

E = image illuminance in foot-candles
πB = object brightness in foot-lamberts
θ = image semi-convergence angle

The estimated brightness level of the 5AZP4 at the previously mentioned operating condition is 2200 foot-lamberts (from RCA data sheet). Therefore:

$$E = 2200\ (.0831)^2 = 15.2 \text{ ft.-candles.}$$

The 15.2 ft-candle figure is ideal and does not take into consideration optical transmission and reflectance losses.

1.3.2.2 Projection Screen. - The gain curve of a theoretically ideal screen would plot as a horizontal straight line from a 0° viewing angle to the maximum viewing angle desired, at which point it would turn 90° and drop vertically, thereby showing the compression of projector light within this angle. The ideal screen would also have a maximum "gain" or screen brightness for the entire viewing azimuth. Therefore, the efficiency of a practical screen is gauged by the flatness of its plotted curve. However, screens of low light transmission, even with a flat curve, are not efficient because of light lost by reflectance. The most efficient practical screen then is a compromise, based upon the circumstances, between the factors of projector light available and viewing angle required.

For the case at hand, light available from the projector is at a premium, therefore a high gain screen is a positive requirement. Many screen manufacturers were contacted and a number of screen samples were obtained, both in glass and plastic. Among the most promising are the Eastman-Kodak Company's Day-View Screens and the Trans-Lux 'Luxchrome' screen. The Day-View type 1 is a white screen made of 1/8" glass with one surface ground. It offers the highest gain of all screens tested, along with reasonable gain fall-off with viewing angle as shown in Figures 12 and 13. Figure 13 shows that if 58 ft-lamberts are emitted from the projector, 30 ft-lamberts will be available at the viewing surface of the rear projection screen EK Type 1. The Luxchrome screen has a somewhat better fall-off characteristic but its gain is about 2/3 that of the EK Type 1 due mainly to its gray tint. It is made of fairly stiff plastic material about 1/32" thick. The gray tint seems to offer better image contrast when the screen is viewed in a lighted room. A 50" x 50" Luxchrome screen has just been obtained for demonstration purposes. A slide transparency of a simulated PPI will be projected upon this screen at various brightness levels and ambient room lighting conditions. This will serve to provide a better understanding of problems to be encountered in viewing such a very large PPI display.

An investigation was conducted in the fields of electroluminescent light amplifying panels and image light conversion. Basically, an electroluminescent light amplifying panel uses a photoconductive layer electrically in series with an electroluminescent phosphor layer. With the series combination excited by an alternating voltage of audio frequency, e.g. 400 CPS, a low light level impinging on the photoconductor decreases its resistance sufficiently to cause a much larger light output from the phosphor. Light amplifying panels 12 inches square have been built. These panels are capable of producing intensified images with very high resolution. The response time of these panels, determined basically by the photoconductive material, varies from 0.1 sec. to several seconds. Light gain may be in the order of ten times. At the present time, however, these devices are in the development stage and any application requirements would have to be 'hand tailored' in the laboratory.

In the so-called image light conversion technique, the light emission from the projector which falls outside the visible region, i.e., 4000 to 7000 A°, can be converted to visible light by the use of certain phosphors. These phosphors, such as (Zn, Cd)S:Ag, are activated by ultraviolet and infrared radiation and have peak emission near 5500 A°; the wavelength (yellow-green) to which the eye is most sensitive. With the emmission characteristics of the 5AZP4, a thin phosphor coating on a projection screen may afford a 20% increase in light output from the screen. An additional feature is the wider viewing angle obtained due to the phosphor diffusion characteristics.

1.3.2.3 <u>Advantages of a Vertical Display vs. Horizontal Display</u>. - A study of the optical and human engineering factors relative to the RATCC display system indicates that a vertical PPI display offers a number of significant advantages to a horizontal display of equal size (50 inch dia.). These advantages are enumerated below.

(1) A vertical display offers considerable increase in light output available to an operator due to improved viewing conditions. A large horizontal display will generally be viewed obliquely, the viewing angle varying for 0° at display edge adjacent to operator, to 38° at screen center and to 57° at display edge farthest from the operator. These conditions pertain to a 50 inch diameter view field with an average height operator standing adjacent to the display unit. A high quality rear projection screen such as the type I (specially treated for high gain) made by Eastman Kodak Co. has a relative brightness of 100% at 0° view angle, 12% at 38° and 5.6% at 57°. This is quite a rapid "fall off" with view angle but is indicative of what is obtainable with the best available rear projection screens. Moreover, the total azimuthal view angle is about 60°: much too wide an angle for full appreciation of the entire image field (if this is desired). Stepping back somewhat from the display unit in order to reduce this view angle aggravates the obliqueness condition.

(2) A great increase in image contrast may be obtained by providing a vertical display instead of a horizontal display with the same image brightness and ambient illumination. The following reasoning pertains: since the ambient illumination specified (15 ft-candles) is that which impinges on the horizontal display surface, only about half that illumination would be measured on a vertical surface at that same location (with the usual diffusion characteristics of office illumination).

(3) A vertical display system does not require the large reflecting mirror used to redirect the light beam in the horizontal display. This mirror is elliptically shaped, 30 x 45 inches, and about 3 inches thick. This mirror with its attendant adjustments may cost several thousand dollars. Elimination of this mirror -

(a) does not increase projection distance
(b) increases image brightness 5 to 10%
(c) materially reduces maintenance time required for adjustment and care of the display system.

(4) The vertical display is ideal for group instruction purposes.

(5) The vertical display makes possible the use of a shade 'hood' if desired.

(6) The vertical display provides greater operator comfort and efficiency, especially for prolonged viewing periods.

(7) Since the projection screen in the vertical display is retained in a vertical position, its thickness can be considerably reduced because of less peripheral stress due to its own weight. In addition, there is less likelihood of heavy weights being placed upon it. This means less cost and greater safety.

1.3.2.4 X-Ray Protection Requirements. - We may regard the inner surface of the 5AZP4 projection kinescope tube face as an X-ray source when struck by electrons which have been accelerated through 40 kilovolts. The tube beam current is about .3 ma. The minimum observer distance will be about 8 feet from the source, and at least a 1/2 inch of glass will be interposed (1/4 inch Schmidt corrector plate and 1/4 inch screen) between the X-ray source and observing personnel.

From Handbook 50, National Bureau of Standards, X-ray protection design,

$$Y_u = 9.7 \times \frac{C^2}{i} \times 10^{-6}$$

Therefore,

$$Y_u = 9.7 \times \frac{8^2}{.3} \times 10^{-6}$$

Y_u = dosage rate to find required Pb equivalent of barrier to reduce dose rate to within maximum permissible value.

C = distance in feet between target and personnel.

i = target current in milliamperes.

From an experimentally derived curve, this is equivalent to .017 cm Pb = .0067 in. Pb. To find the equivalent glass thickness of this lead barrier whose density is $11.34 \times 10^3 \frac{Mg}{Cm^3}$

$$X \frac{Mg}{Cm^2} = 11.34 \times 10^3 \frac{Mg}{Cm^3} \times .017 \text{ cm} \cong 193 \text{ Mg/Cm}^2$$

For glass the density $\rho = 2.5 \times 10^3 \frac{Mg}{Cm^3}$

$$\frac{193}{2.5 \times 10^{3}} = X \text{ cm glass} = 77.2 \times 10^{-3} \text{ cm. or about } 1/32 \text{ inch}$$

to reduce the dose rate to within maximum permissible levels. Actually there will be a minimum of glass (1/2 inch) present. This is about 16 times the required thickness. Moreover, an additional safety factor exists because:

(1) The equation assumes an X-ray tube, which optimizes the generation of X-rays for the tube current present. Generation of X-rays in the kinescope is incidental and below optimum (actually the X-ray intensity is about one-third of that given by the equation).

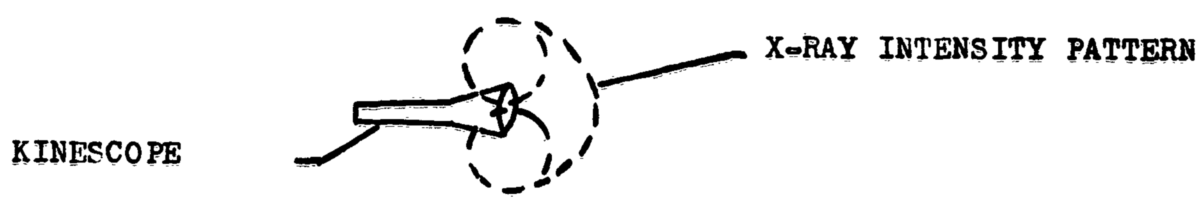
(2) Curve used is for 50 Kev. X-rays, which are more penetrating than the 40 Kev. maximum X-rays present in our system.

(3) Observers will generally be at a greater distance than used in the calculation.

(4) The equation implies isotropic distribution of X-radiation. Actually, the position of the observer is such compared to the initial direction of the electron beam that less than isotropic intensity will be present at the observer position.

For servicing and optical adjustment of the system, it may be desirable to get very close to the kinescope while it is operating and with the projector barrel cover removed. An estimate of the x-ray dosage rate to which service personnel would be exposed under these conditions is therefore useful.

Assume tube operating conditions as previously mentioned and a lateral distance of 18 inches from the source. When 40 kilovolt electrons are impinged on a scattering surface, the x-rays formed are scattered toroidally, with axis of symmetry along the electron beam path as shown below.



Therefore, the intensity broadside to the tube is much as if the tube were an inefficient X-ray tube.

The efficiency of an X-ray tube is given by:

$$\text{Efficiency} = \frac{\text{X-ray energy}}{\text{Cathode-ray energy}} = 1.4 \times 10^{-9}\, ZV$$

Where: Z = atomic number of target
V = potential drop in volts

For a tungsten anode X-ray tube at 40 kilovolts, X-ray efficiency is equal to $1.4 \times 10^{-9} \times 74 \times 40 \times 10^3 = .00414$.

An average atomic number for the phosphor of the kinescope is probably under 25. Therefore, the efficiency of the kinescope as a generator of X-rays has an upper bound equal to: $1.4 \times 10^{-9} \times 25 \times 40 \times 10^3 = .0014$.

Since the X-ray intensity distribution perpendicular to the kinescope axis resembles that of an X-ray tube, a nomograph of dosage rate as a function of tube operating parameters can be used, and the relative efficiencies as X-ray generators applied.

For a tungsten anode X-ray tube, at 40 kilovolts and .3 ma, the X-ray beam at 18 inches yields a dosage rate of 21.6 roentgens per/hour.

For the kinescope, the dosage rate at the same distance would be of the order

$$\frac{.0014}{.00414} \times 21.6 \text{ roentgens/hour} = 7.35 \text{ r/hr}$$

This dosage rate is far too great to allow routine adjustments to be made without protection even though the X-ray beam is quite soft. What thicknesses of several shielding materials would be required to reduce this intensity to safe levels? Present maximum permissible dose is set at 100 milliroentgens/week, or 2.5 mr/hour for a 40 hour work week. The equation which governs reduction of the intensity is:

$$I = I_o e^{-u_o X}$$

Where:

I = transmitted intensity
I_o = initial intensity
u_o = attenuation constant
X = thickness of attenuating material
e = 2.718

Therefore:

$$\frac{2.5}{7.35 \times 10^3} = {}^{-u_o x}$$

$$e^{-u_o x} = .00034$$

$$e_o x = 8.00$$

The table below shows the thicknesses of several common shielding materials required to attenuate the X-ray intensity to the maximum permissible level for an operator at an 18 inch lateral distance from the kinescope faceplate. A cylindrical projector barrel cover made of aluminum and lined with 1/32 inch of lead would be quite adequate for this purpose. Optical adjustment controls should be external to this shield.

ATTENUATING MATERIAL	U_o/P $\frac{cm^2}{gm}$ (40 Kev)	$\frac{gm}{cm^3}$	u_o cm^{-1}	Thickness X cm.	Thickness X inches
IRON	3.5	7.87	27.6	.29	.12
LEAD	10.1	11.35	114.6	.07	.03
ALUMINUM	.55	2.7	1.49	5.37	2.1
GLASS	.54	2.5	1.35	6.0	2.32

1.4 Conclusions. - A scan conversion system utilizing the Intec TMA403X video transformation tube appears to provide the characteristics necessary to meet the system resolution and linearity requirements.

Use of the 5AZP4 projection-type kinescope can produce the image high-l ght brightness reouired with a considerable reduction in the ultor voltage as compared with the 7NP4.

1.5 Project Performance and Schedule Chart. - A Project Performance and Schedule Chart covering the entire contract period is shown on the following page.

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STAVID ENGINEERING, INC.

PROJECT PERFORMANCE AND SCHEDULE
INDEX NO. NE-010200, ST4

CONTRACT NO.: NObsr 77632

Date:
Period Cov

Unit No.	DESCRIPTION		1959 J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
1	REMOTE UNIT	PD FD MC T																	
2	DISPLAY INDICATOR	PD FD MC T																	
	ENVIRONMENTAL TESTING																		
	TECHNICAL MANUALS																		
	MANUFACTURING DRAWINGS																		
	FINAL REPORT																		
	MICROFILM																		
	ENGINEERING SERVICES																		
	SPARE PARTS																		
	INSTALLATION DRAWINGS																		

Contract Awarded 19 June 1959

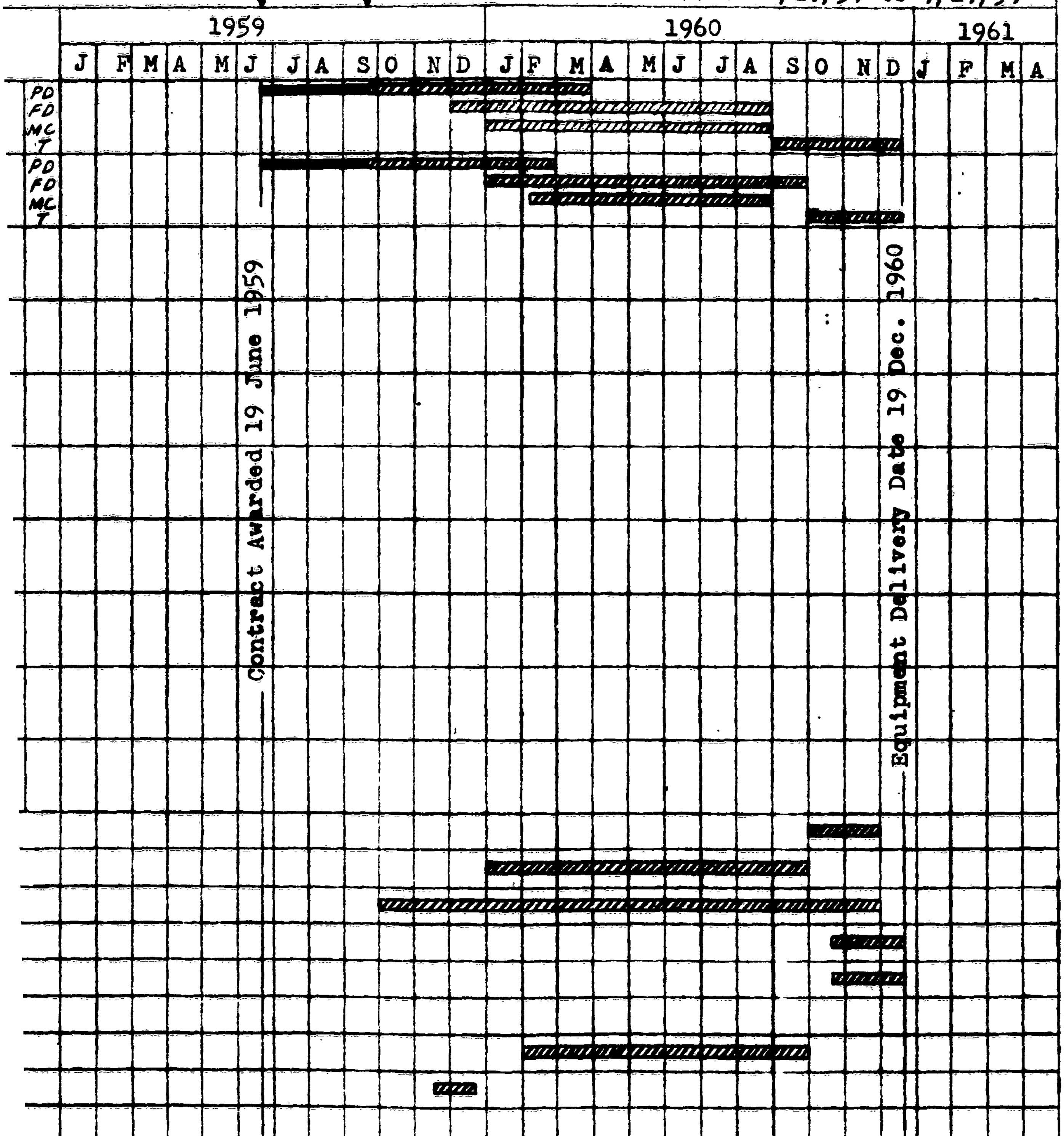
LEGEND:
Work Performed
Schedule of Projected Operations

FD Final Desi
D Drafting

STAVID ENGINEERING, INC.

PROJECT PERFORMANCE AND SCHEDULE
INDEX NO. NE-010200, ST4

Date:
Period Covered: 6/19/59 to 9/19/59



2

cted Operations

FD Final Design
D Drafting
MC Model Construction
T Unit Testing

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SB 4530-18

2. Part II PROGRAM FOR THE NEXT INTERVAL. -

2.1 REMOTE UNIT. -

2.1.1 Scan Circuitry - Breadboarding and evaluation of the timing generator and the sweep generators will continue. The study of the video amplifier requirements will be completed and breadboarding of these components will commence. Consideration will be given to the electrical and physical configuration of the video transformation tube chassis.

2.1.2 Range-Azimuth Circuitry - Testing of the sweep circuitry will continue. Breadboarding of the N-S and E-W sweep amplifiers, clamp, and deflection amplifiers will commence and a preliminary mechanical layout of the drawer will be made. Design and breadboard testing of the two-speed bearing servo unit will be initiated.

2.2 DISPLAY INDICATOR.- Design of the deflection amplifiers will be initiated and the electrical characteristics of the deflection yoke will be determined. Investigations will continue to evaluate the resolution capability of the Schmidt Projector System utilizing the 5AZP4.

3. **Part III ILLUSTRATIONS.**

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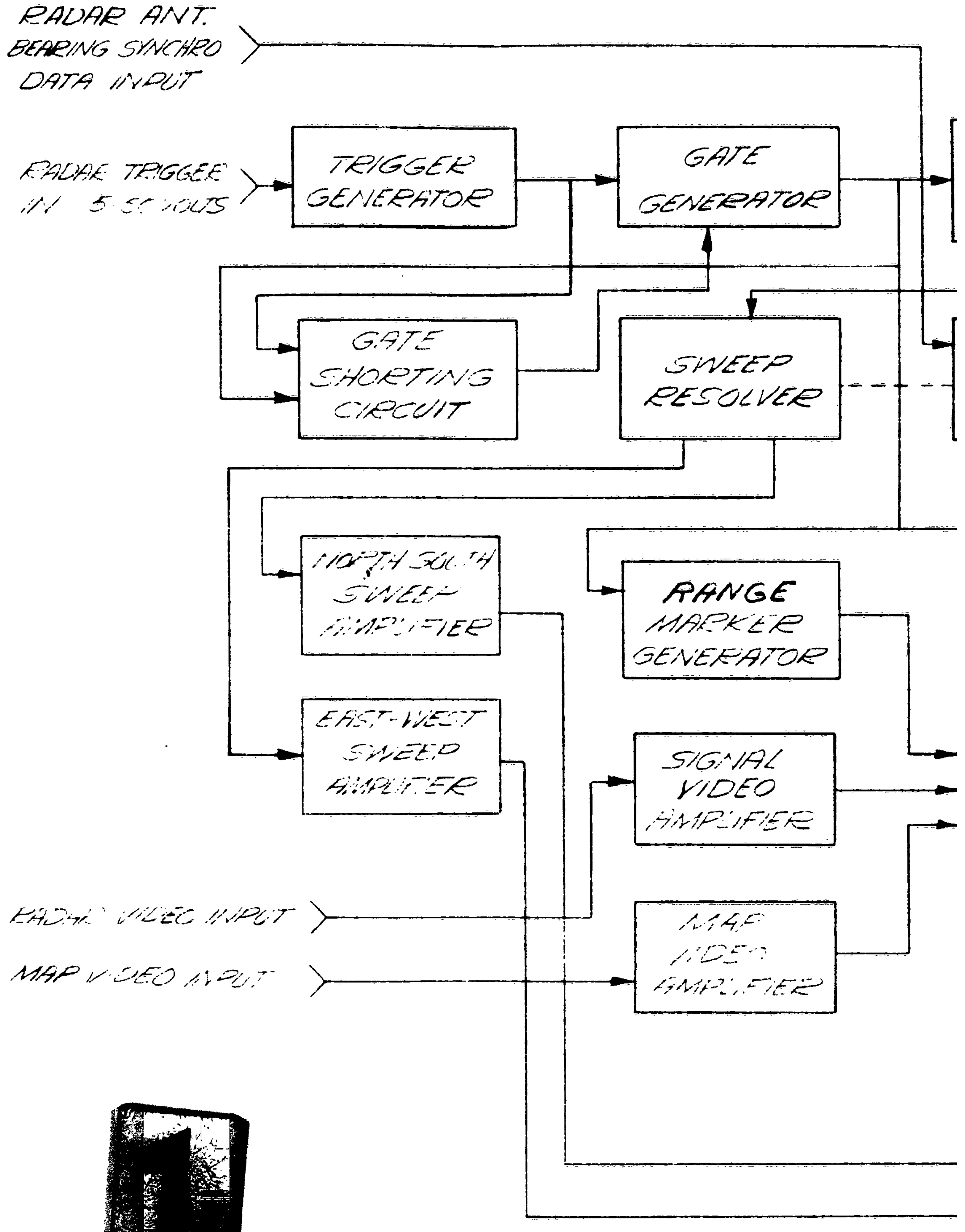

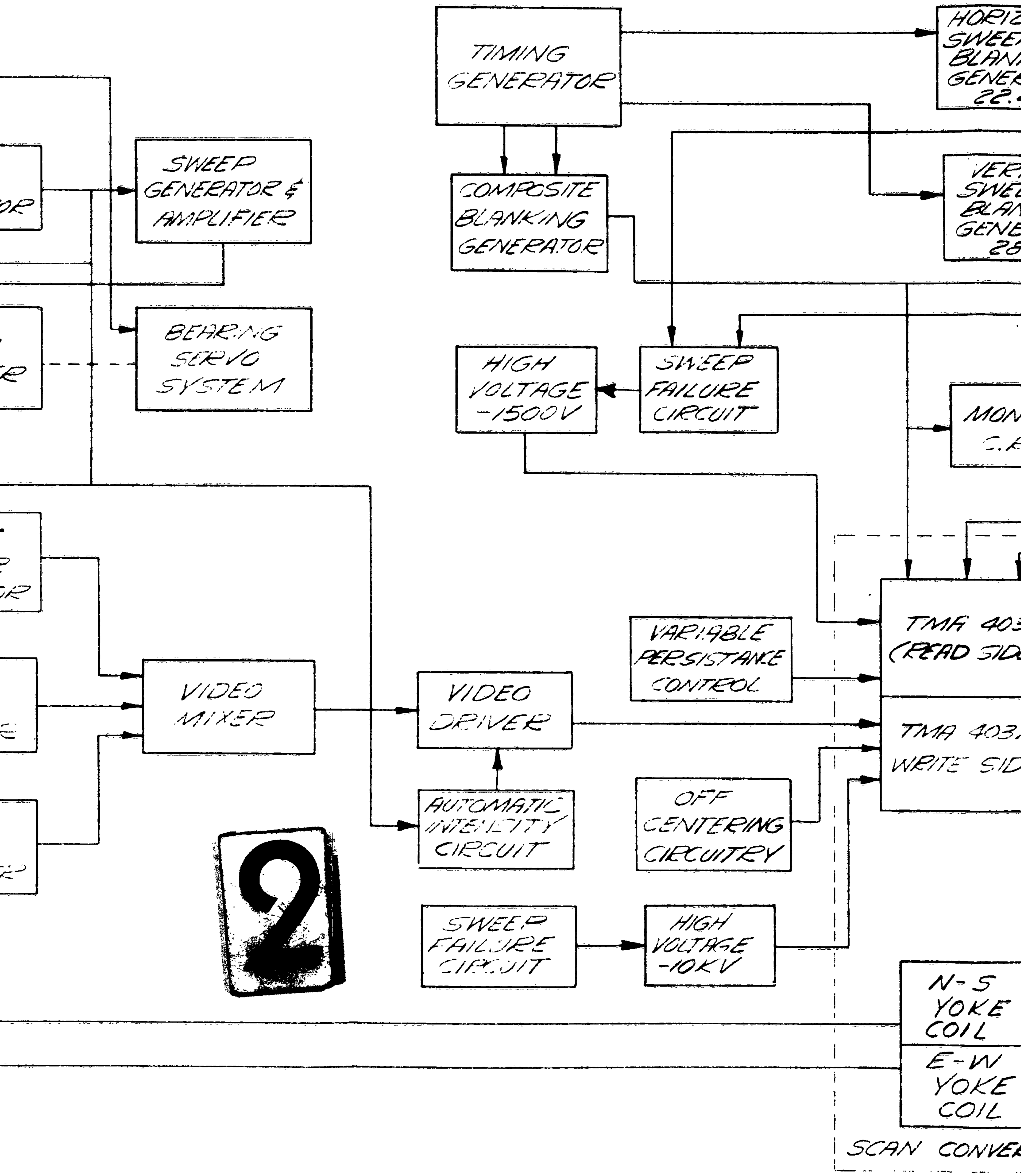
TIMING GENERATOR
COMPOSITE BLANKING GENERATOR
SWEEP GENERATOR & AMPLIFIER
BEARING SERVO SYSTEM
HIGH VOLTAGE -1500V
SWEEP FAILURE CIRCUIT
VIDEO MIXER
VIDEO DRIVER
AUTOMATIC INTENSITY CIRCUIT
VARIABLE PERSISTANCE CONTROL
OFF CENTERING CIRCUITRY
SWEEP FAILURE CIRCUIT
HIGH VOLTAGE -10KV
N-S YOKE COIL
E-W YOKE COIL
2

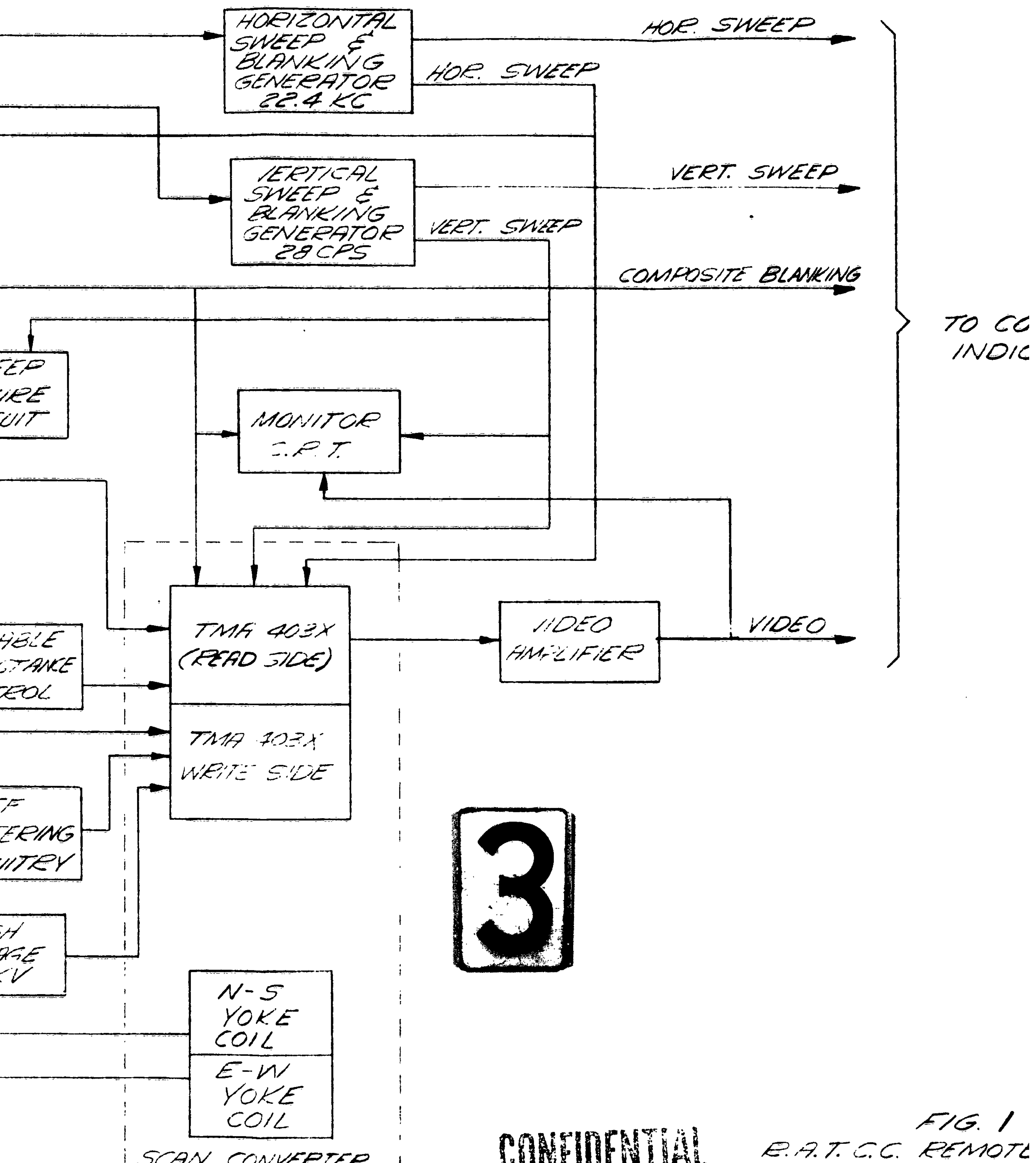

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FIG. 1
R.A.T.C.C. REMOT
BLOCK DIAGR

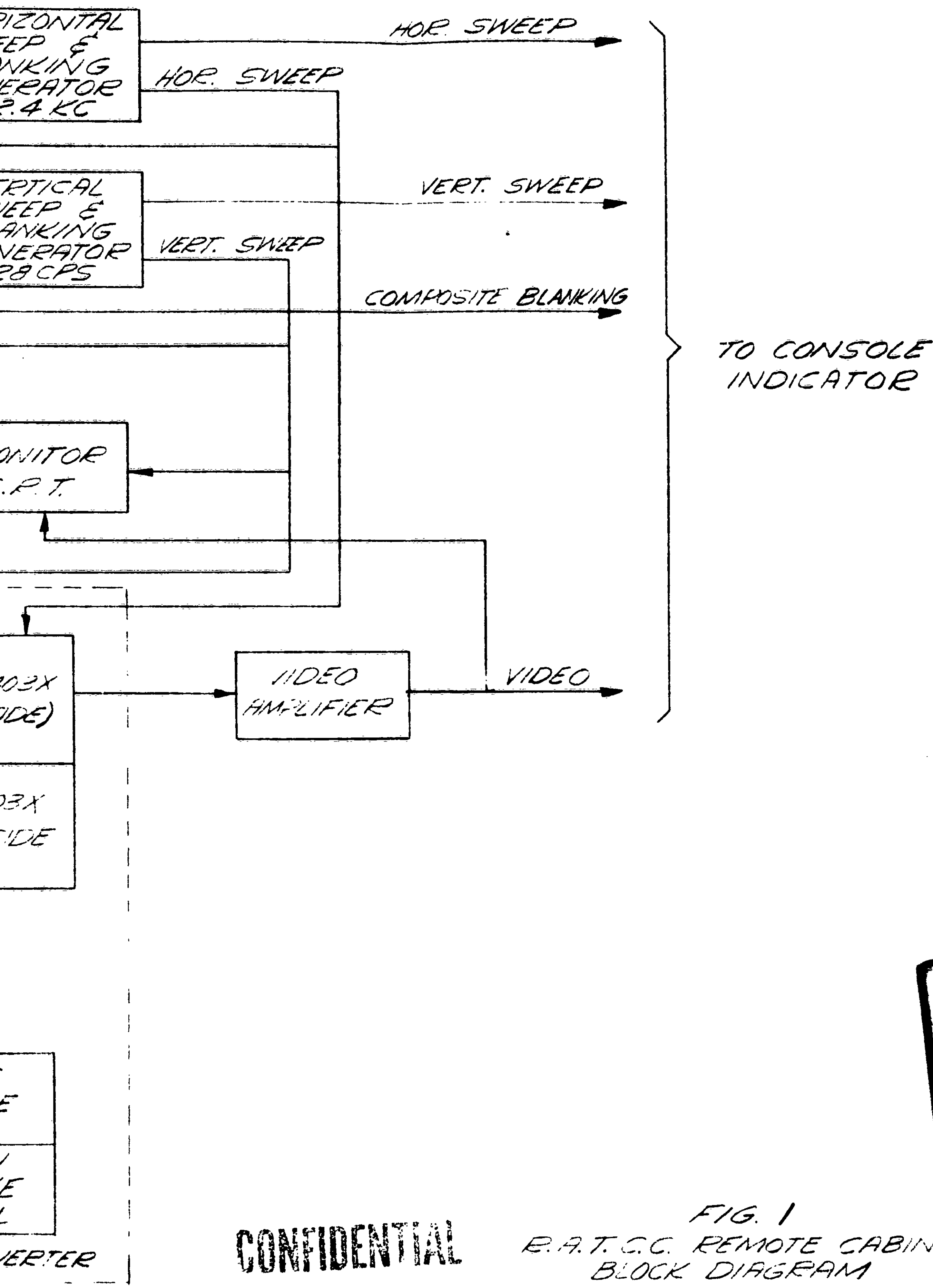

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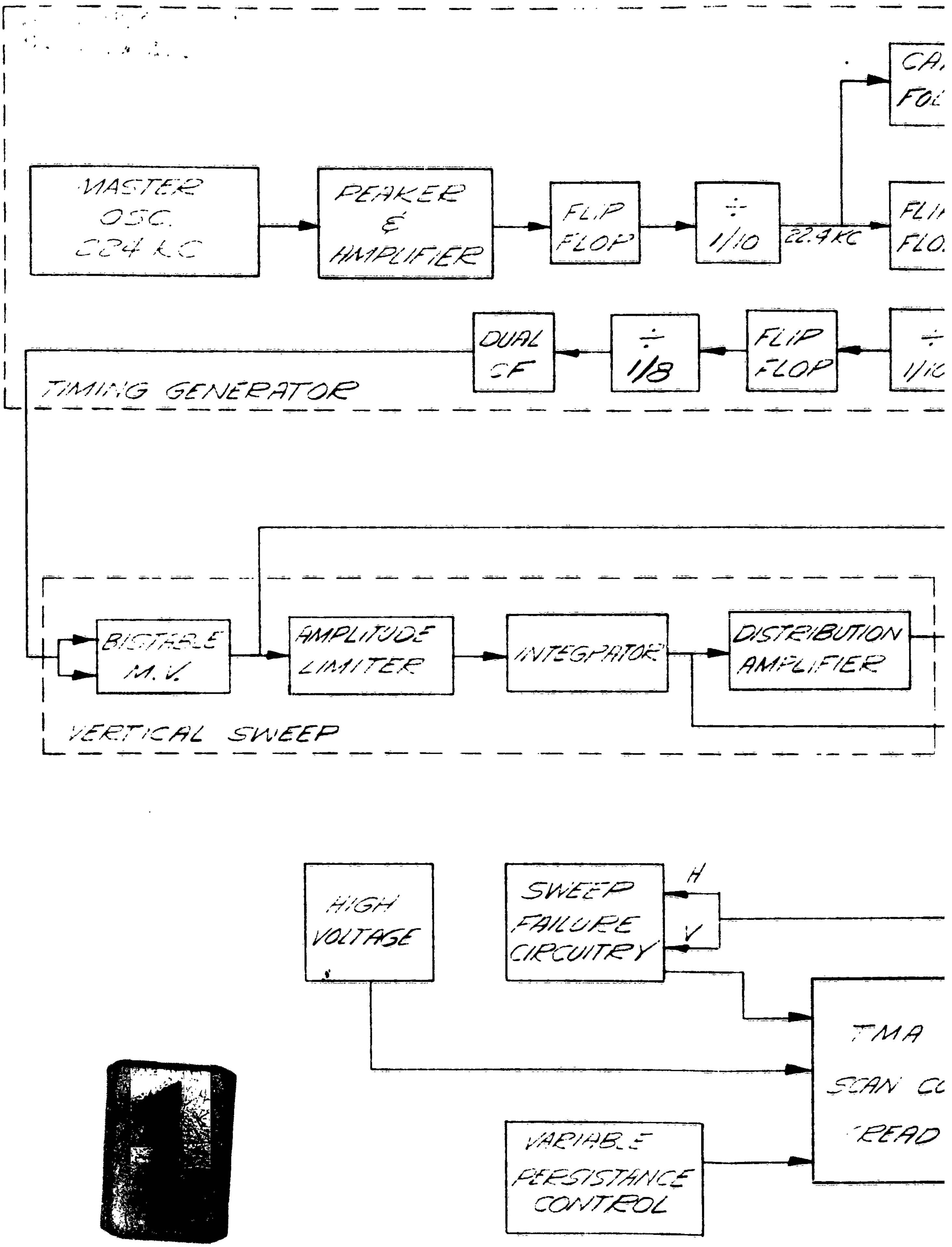
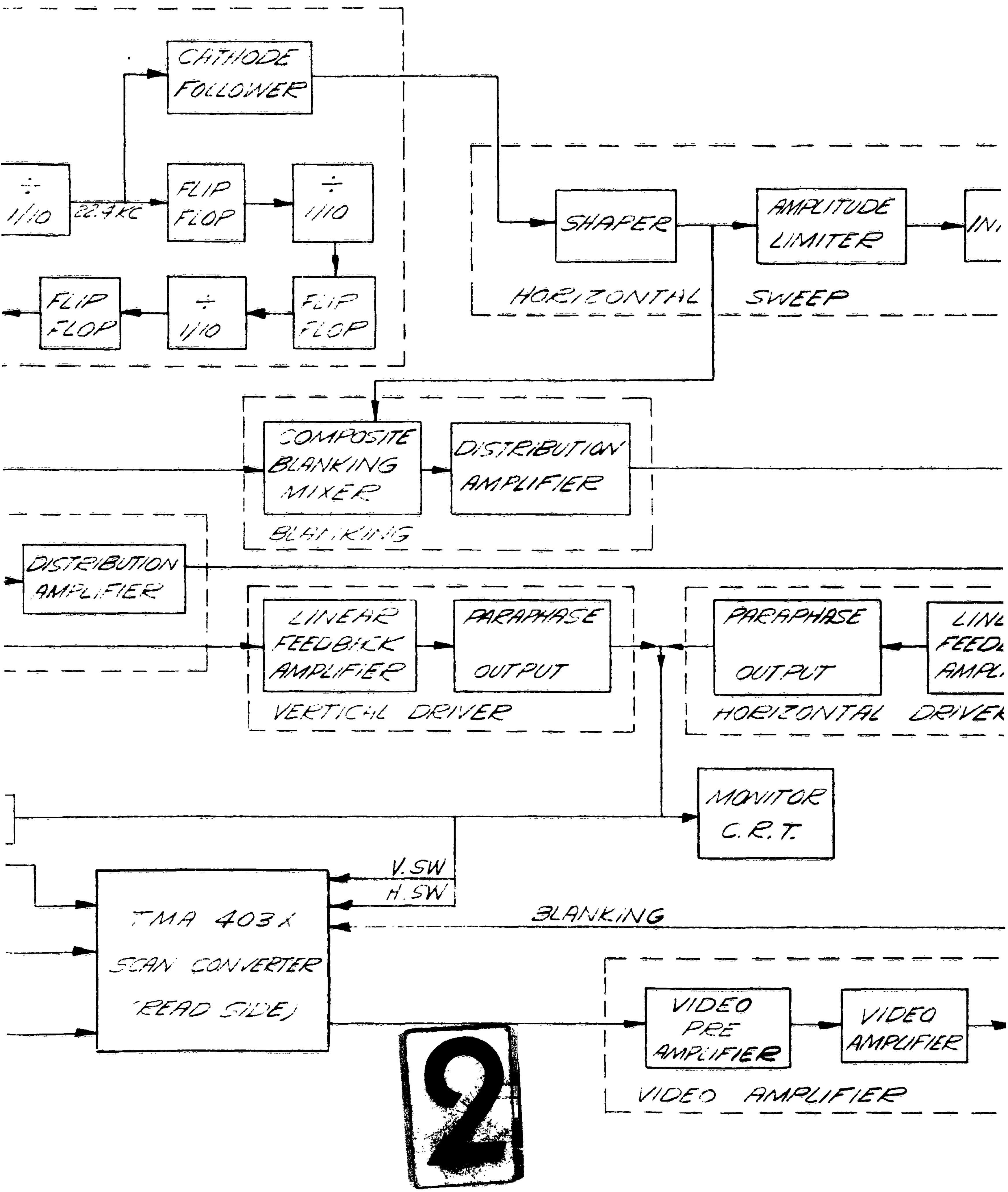
FIG. 1
R.A.T.C.C. REMOTE CABINET
BLOCK DIAGRAM

4


MASTER OSC. 224 KC
PEAKER & AMPLIFIER
FLIP FLOP
÷ 1/10
22.4 KC
DUAL SF
÷ 1/8
FLIP FLOP
TIMING GENERATOR
BISTABLE M.V.
AMPLITUDE LIMITER
INTEGRATOR
DISTRIBUTION AMPLIFIER
VERTICAL SWEEP
HIGH VOLTAGE
SWEEP FAILURE CIRCUITRY
H
V
TMA
VARIABLE PERSISTANCE CONTROL


CATHODE FOLLOWER
÷ 1/10
22.4 KC
FLIP FLOP
÷ 1/10
FLIP FLOP
÷ 1/10
FLIP FLOP
SHAPER
AMPLITUDE LIMITER
HORIZONTAL SWEEP
COMPOSITE BLANKING MIXER
DISTRIBUTION AMPLIFIER
BLANKING
DISTRIBUTION AMPLIFIER
LINEAR FEEDBACK AMPLIFIER
PARAPHASE OUTPUT
VERTICAL DRIVER
PARAPHASE OUTPUT
HORIZONTAL
MONITOR C.R.T.
V. SW
H. SW
BLANKING
TMA 403X SCAN CONVERTER (READ SIDE)
VIDEO PRE AMPLIFIER
VIDEO AMPLIFIER
VIDEO AMPLIFIER
2

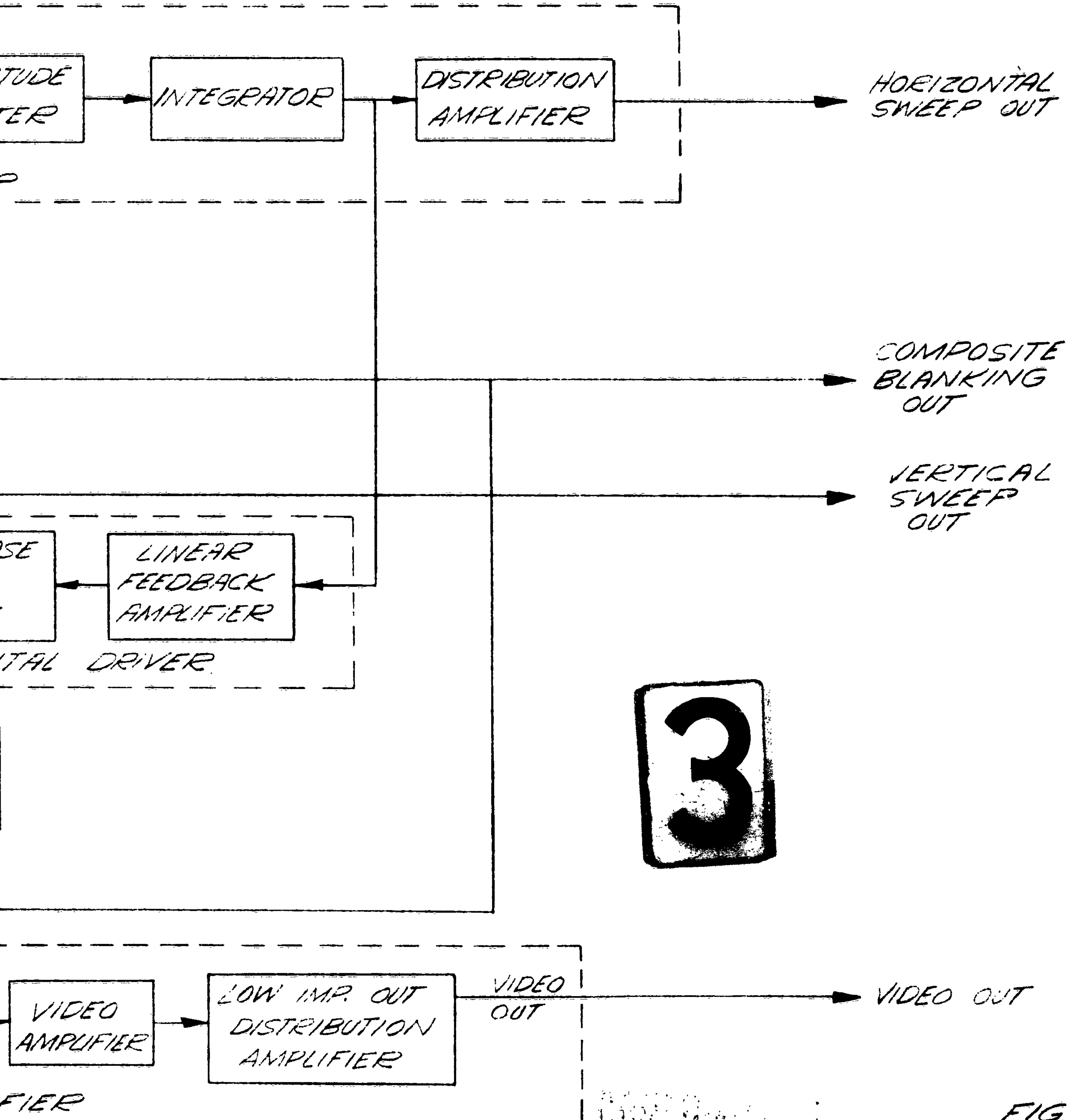


FIG. 2
SCAN READ CIRCU
BLOCK DIAGRAM

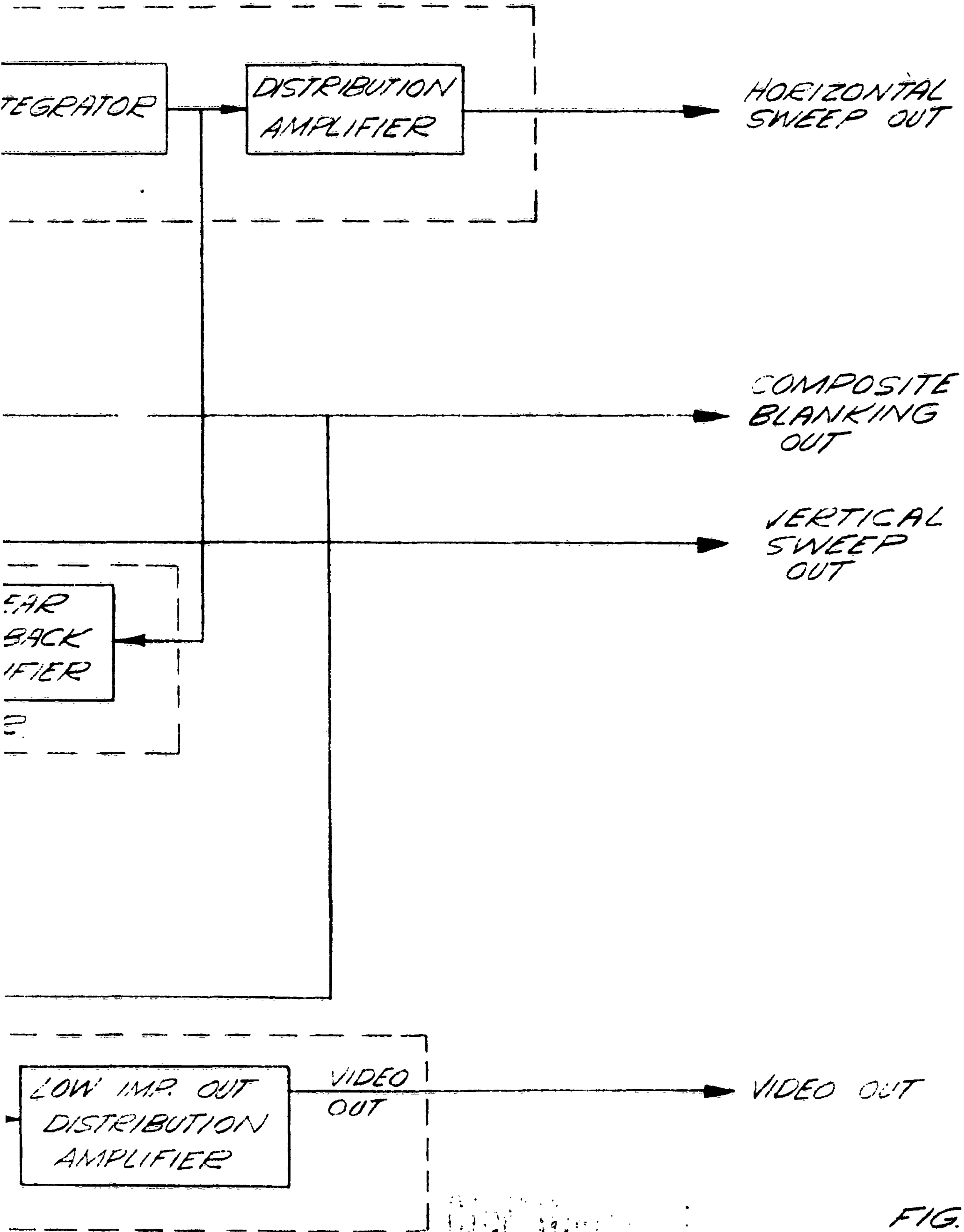
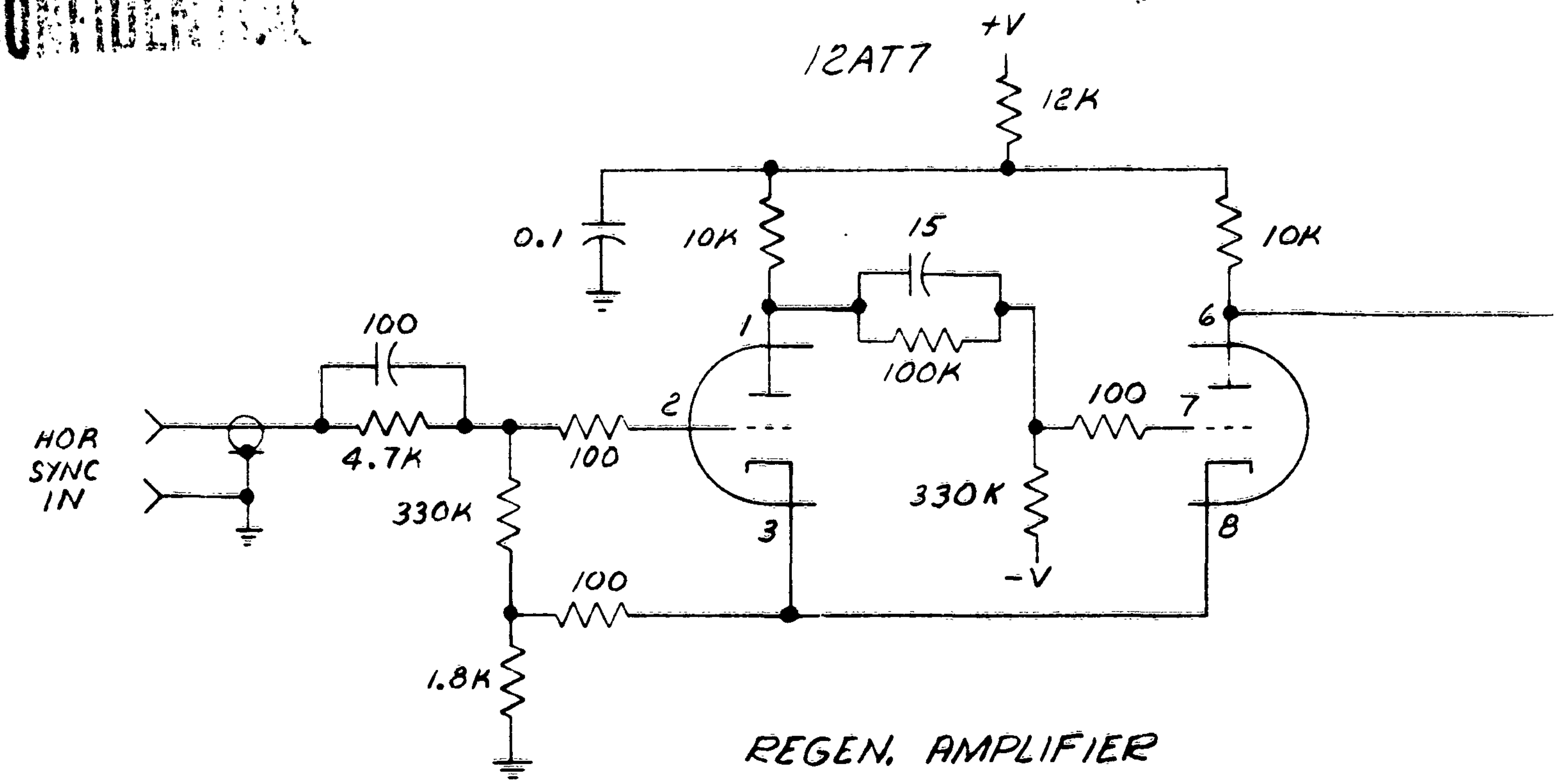
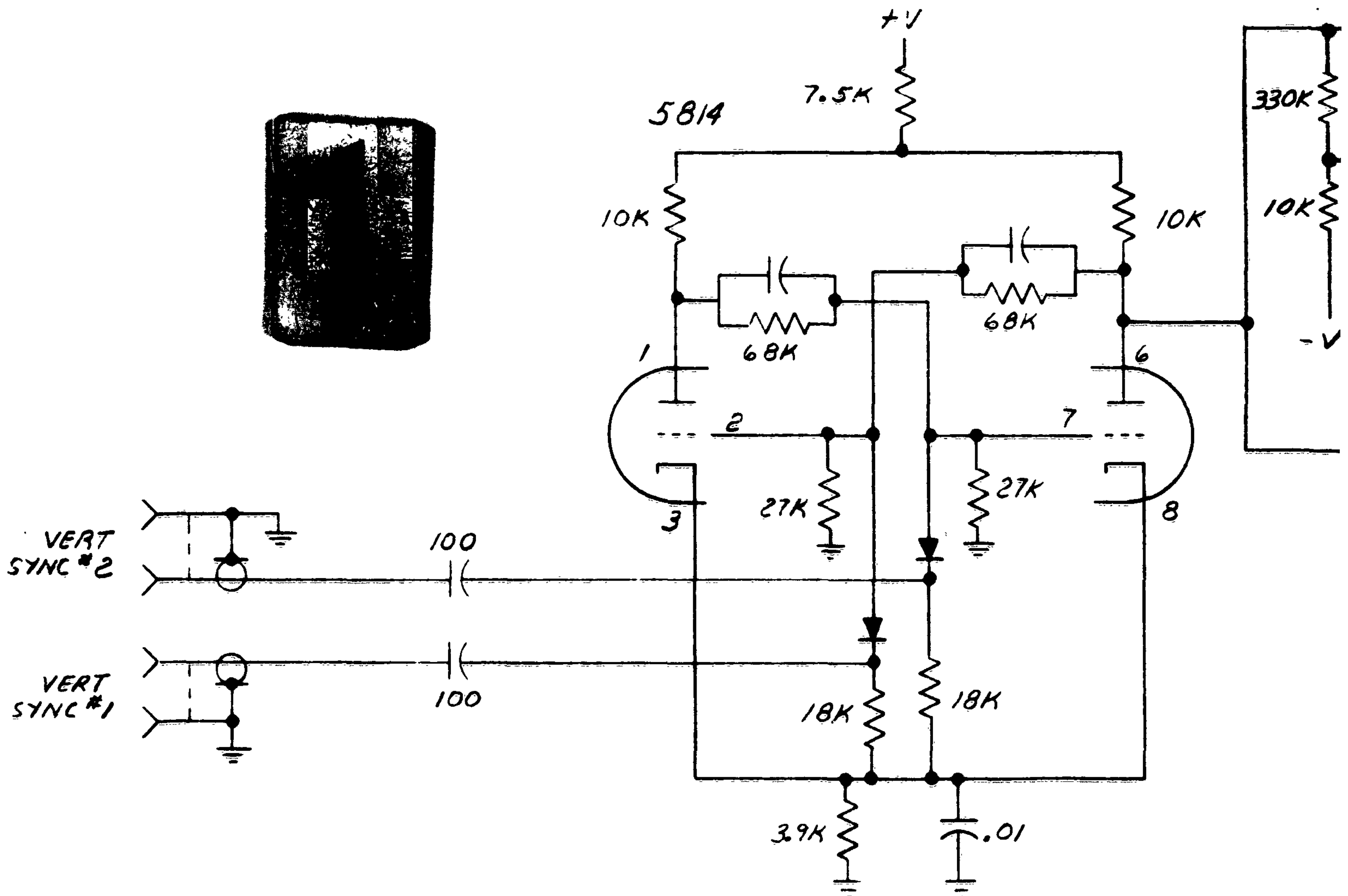


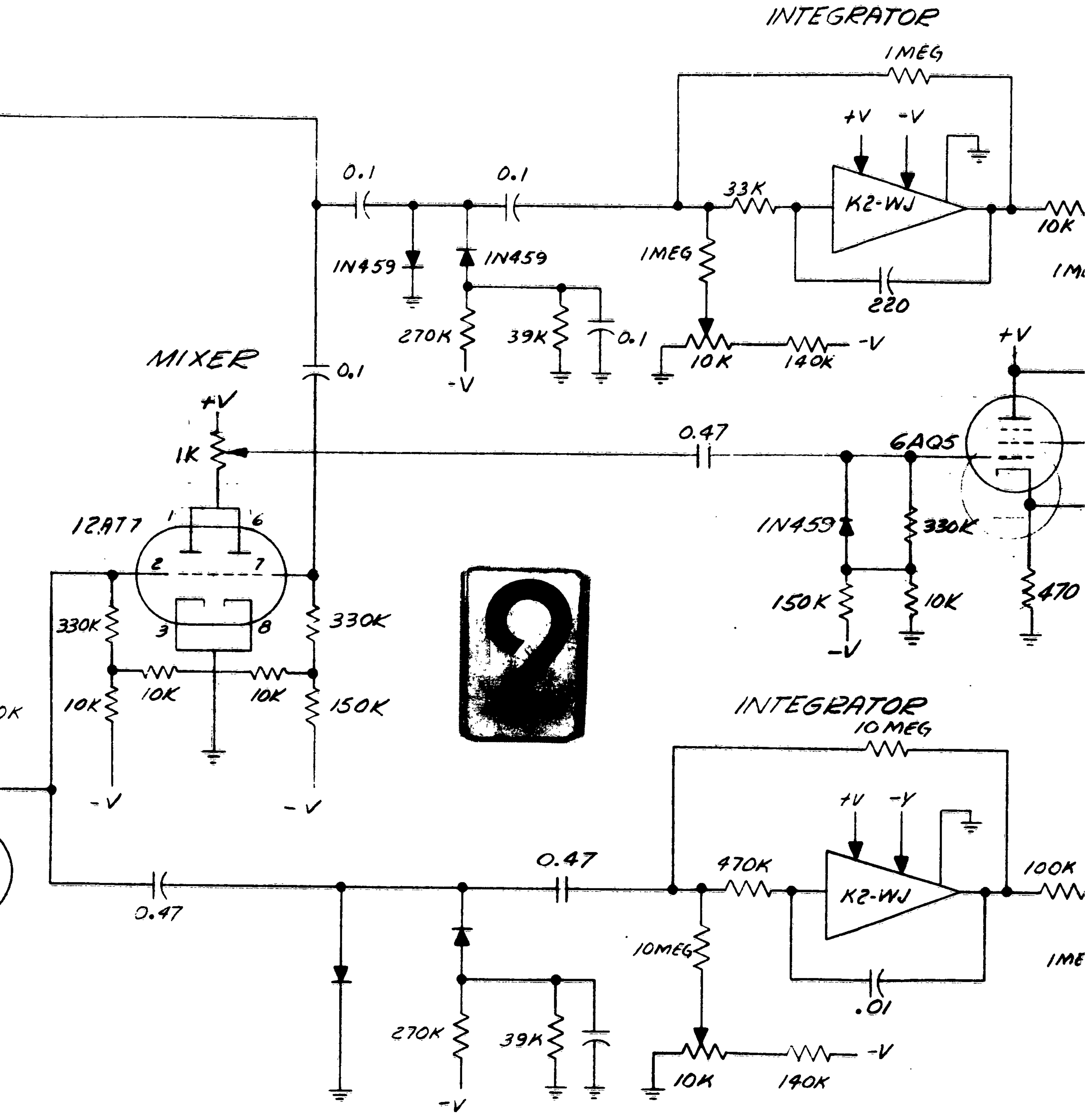
FIG. 2
SCAN READ CIRCUITRY
BLOCK DIAGRAM



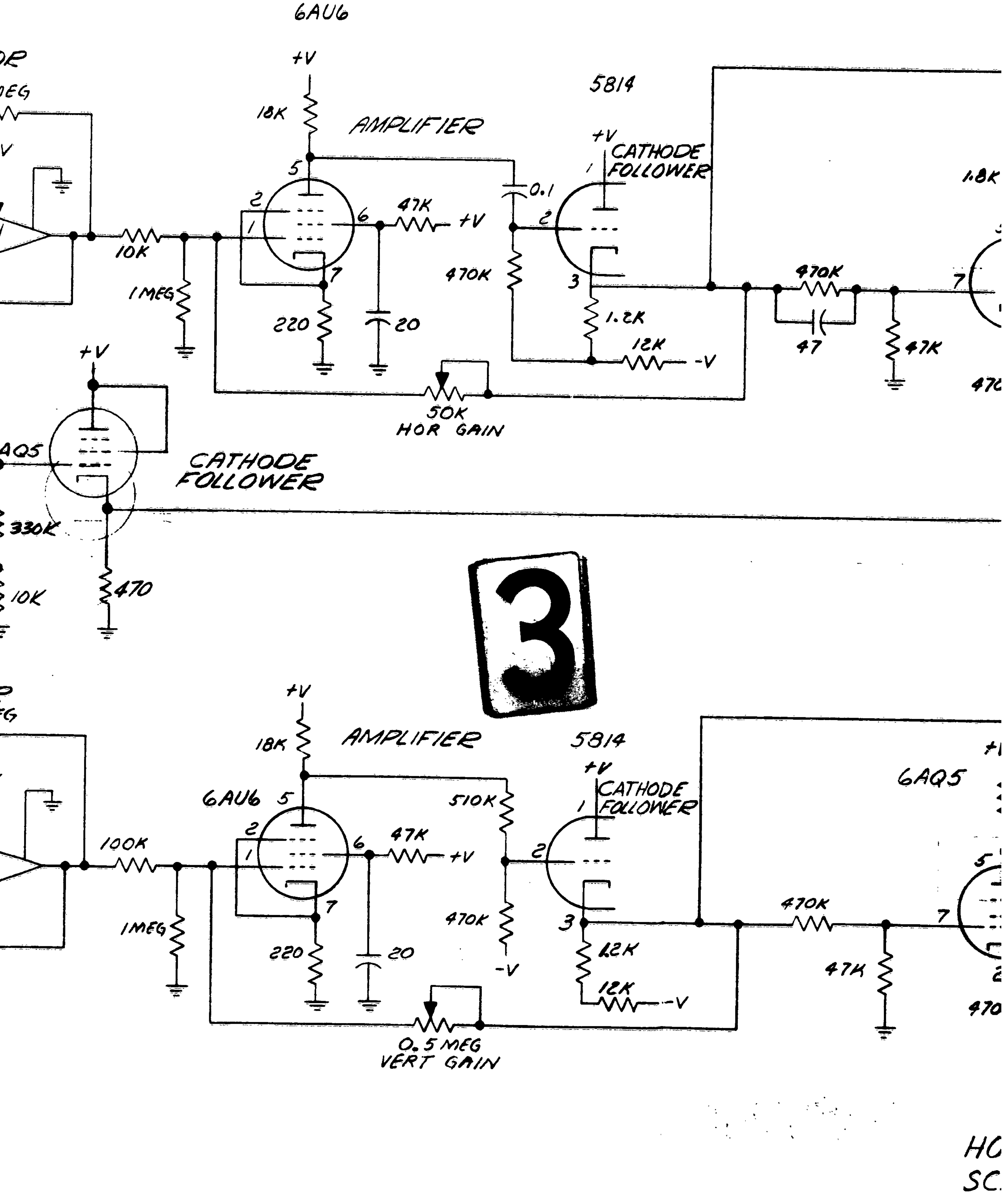
REGEN. AMPLIFIER

BISTABLE
MULTIVIBRATOR





INTEGRATOR
1MEG
+V
-V
0.1
0.1
33K
K2-WJ
10K
1N459
1N459
1MEG
220
270K
39K
0.1
-V
10K
140K
-V
+V
MIXER
0.1
-V
+V
1K
0.47
6AQ5
12AT7
1N459
330K
330K
330K
150K
10K
470
-V
10K
10K
10K
150K
9
INTEGRATOR
10MEG
-V
-V
+V
-Y
0.47
470K
100K
0.47
K2-WJ
10MEG
.01
270K
39K
-V
10K
140K
-V


6AU6
+V
18K
AMPLIFIER
5814
+V
CATHODE
FOLLOWER
1.8K
2
1
5
6
47K
+V
0.1
10K
1MEG
7
470K
3
220
20
1.2K
12K
-V
470K
47
47K
+V
50K
HOR GAIN
6AQ5
CATHODE
FOLLOWER
330K
10K
470
3
+V
18K
AMPLIFIER
5814
+V
CATHODE
FOLLOWER
6AU6
510K
6AQ5
100K
47K
+V
1MEG
470K
220
20
-V
12K
12K
-V
470K
47K
0.5 MEG
VERT GAIN
HO
SC.

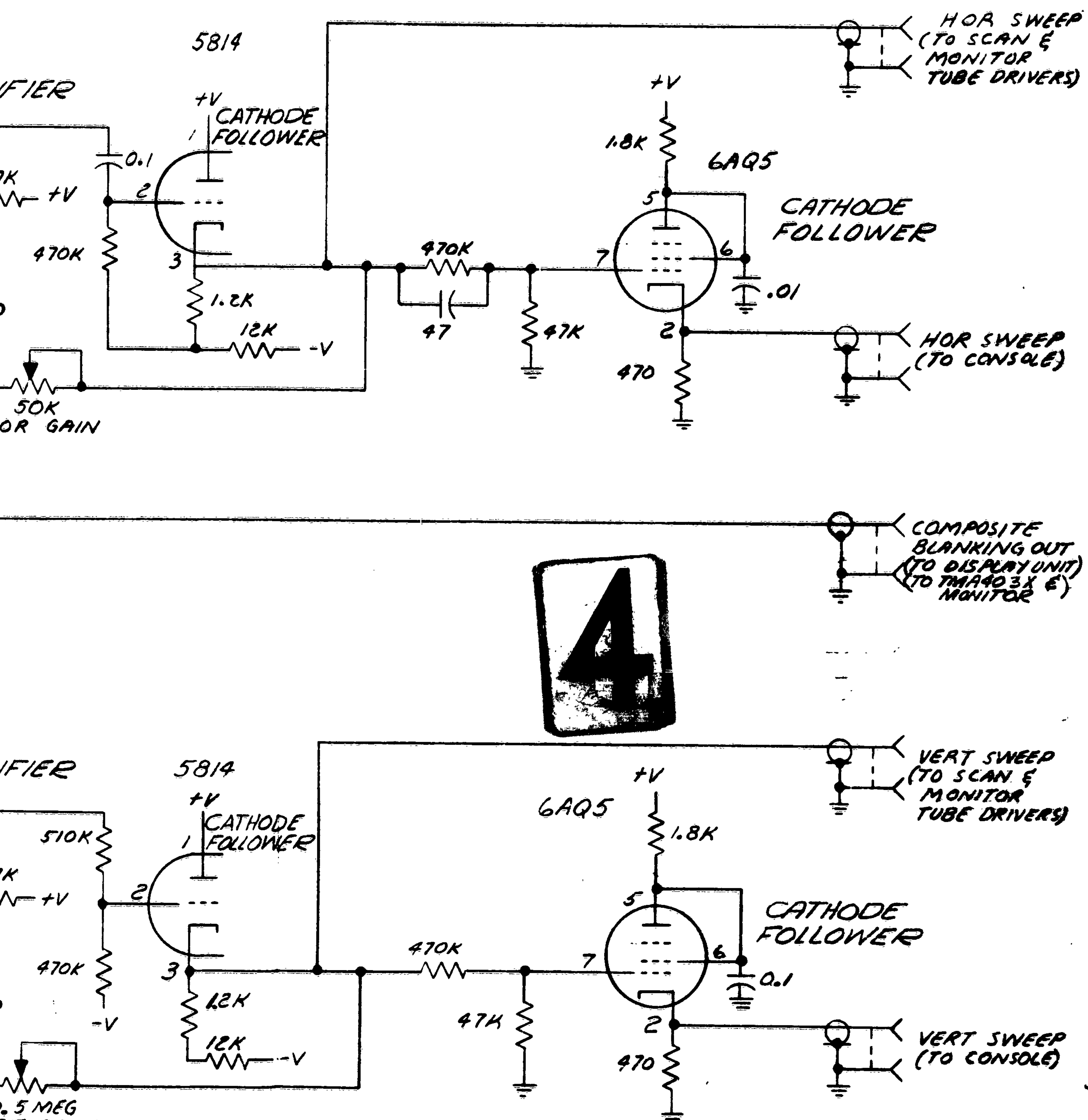


FIG. 3
SCHEMATIC
HORIZONTAL & VERTICAL
SCAN SWEEP GENERATORS

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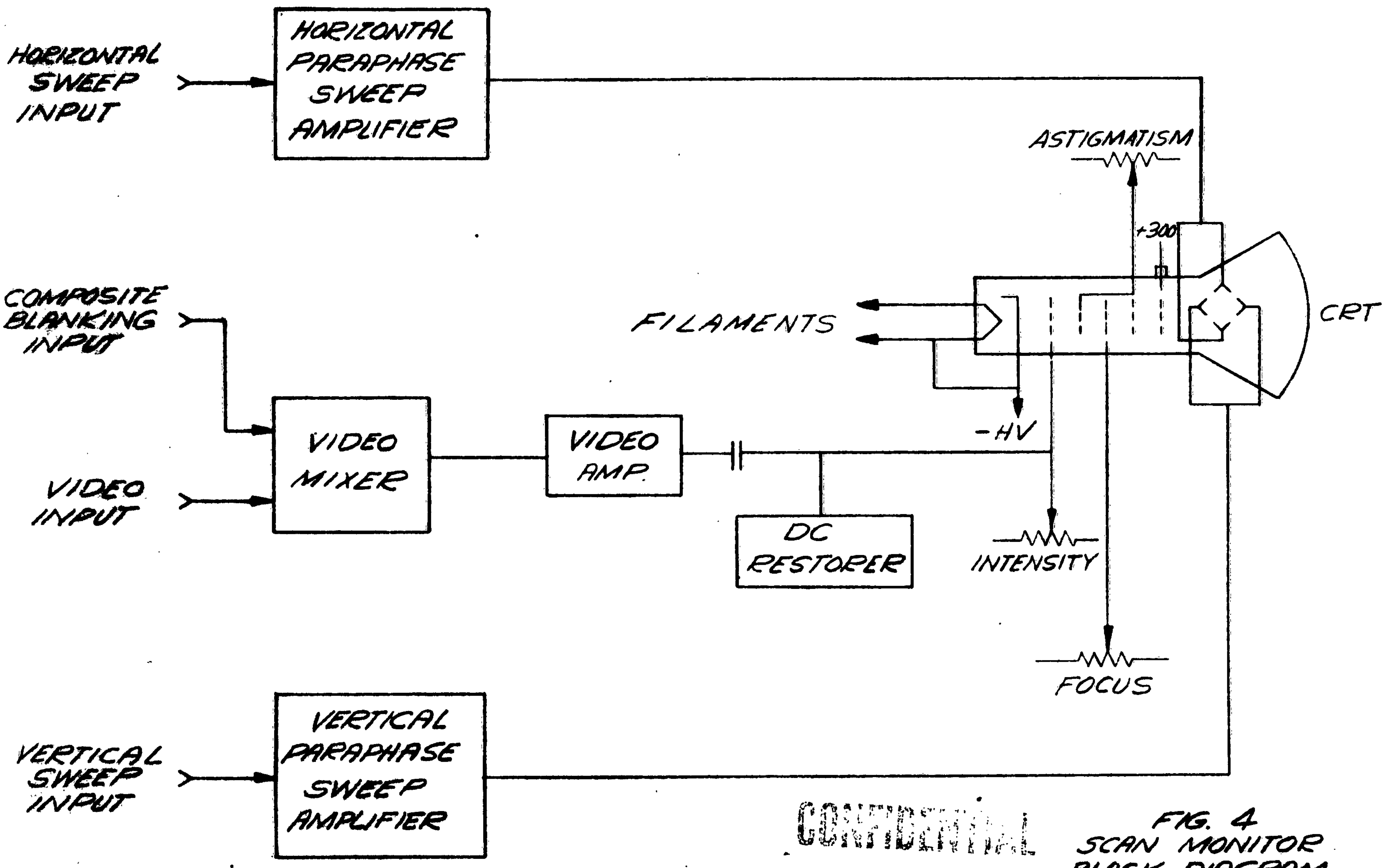

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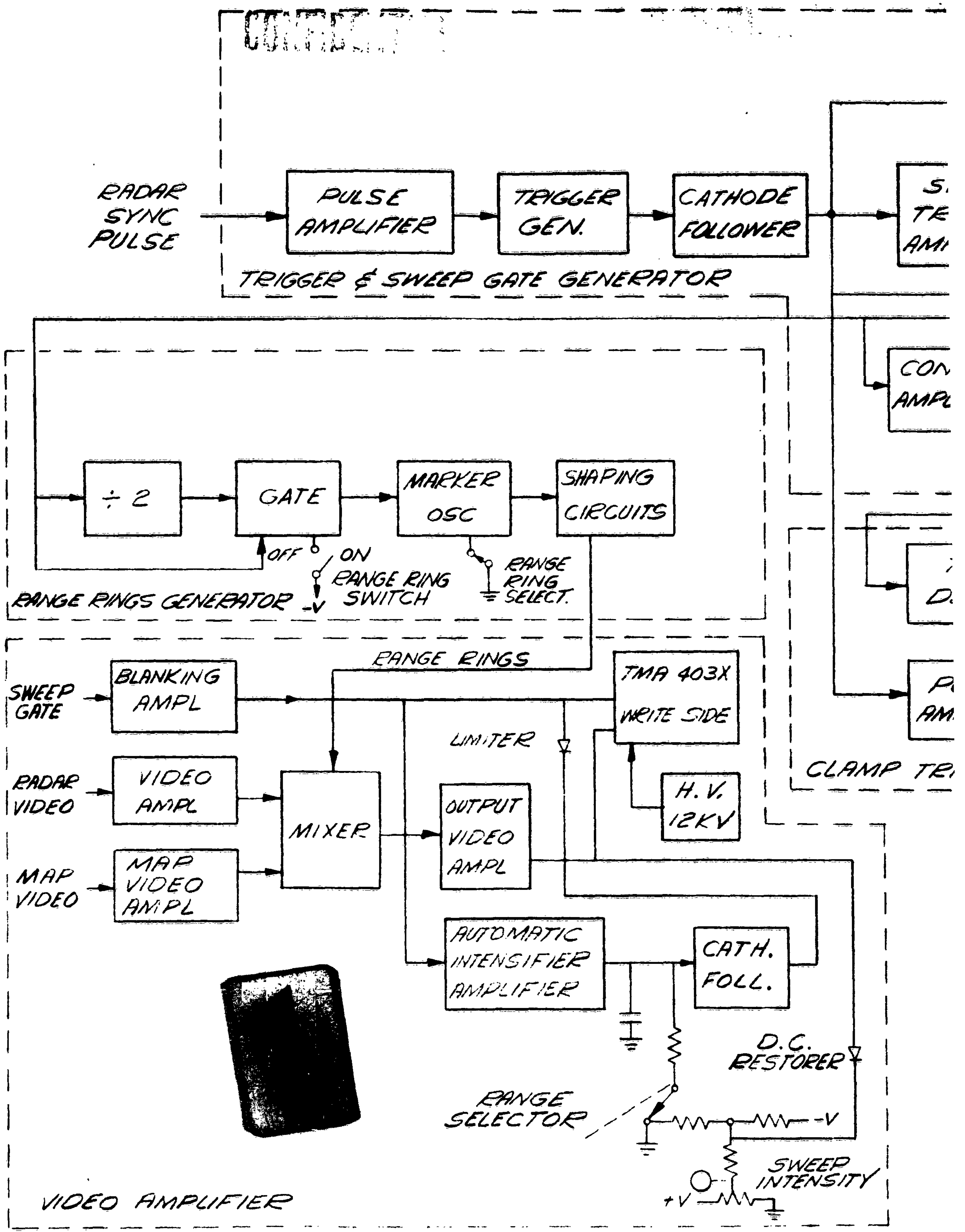
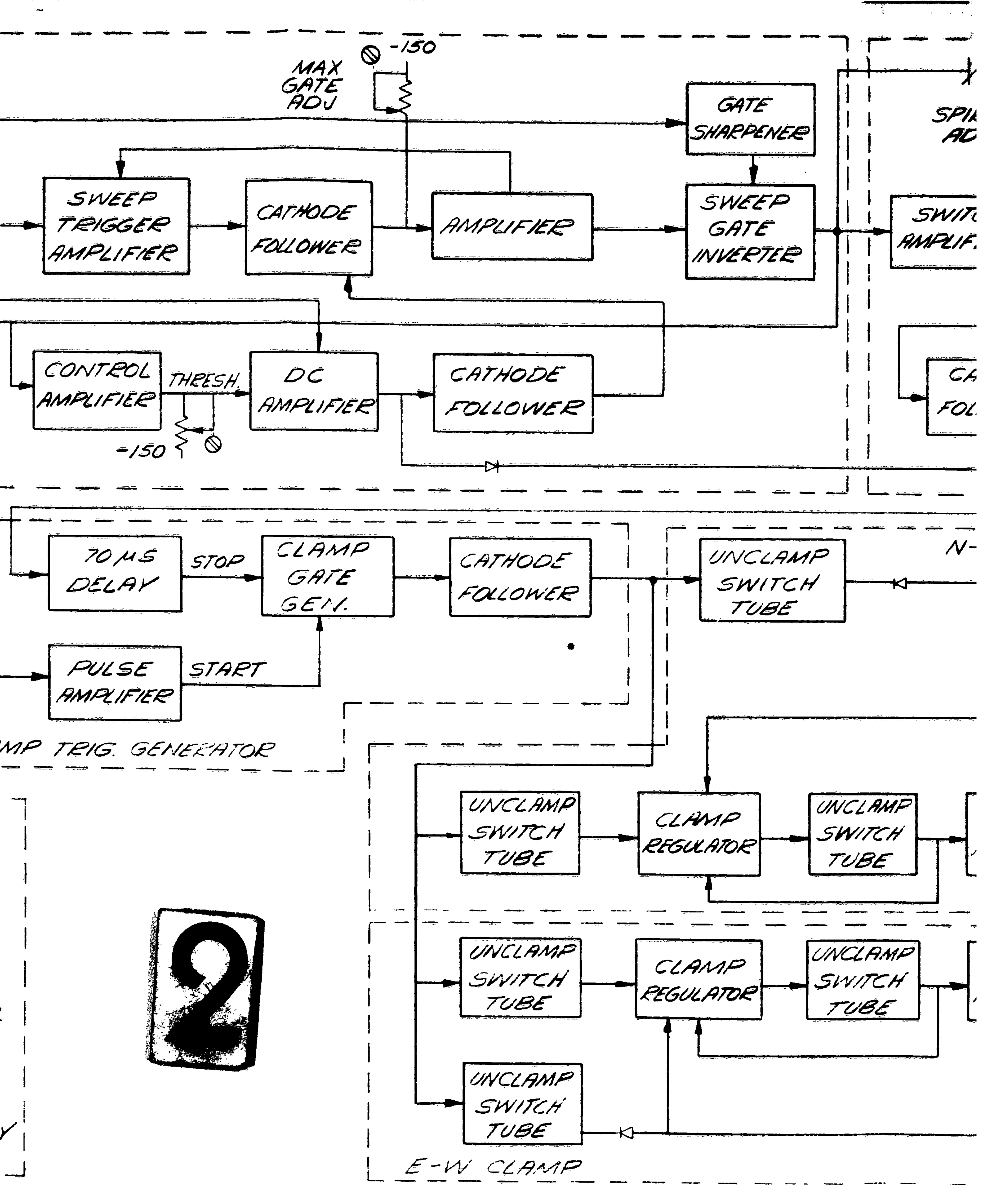
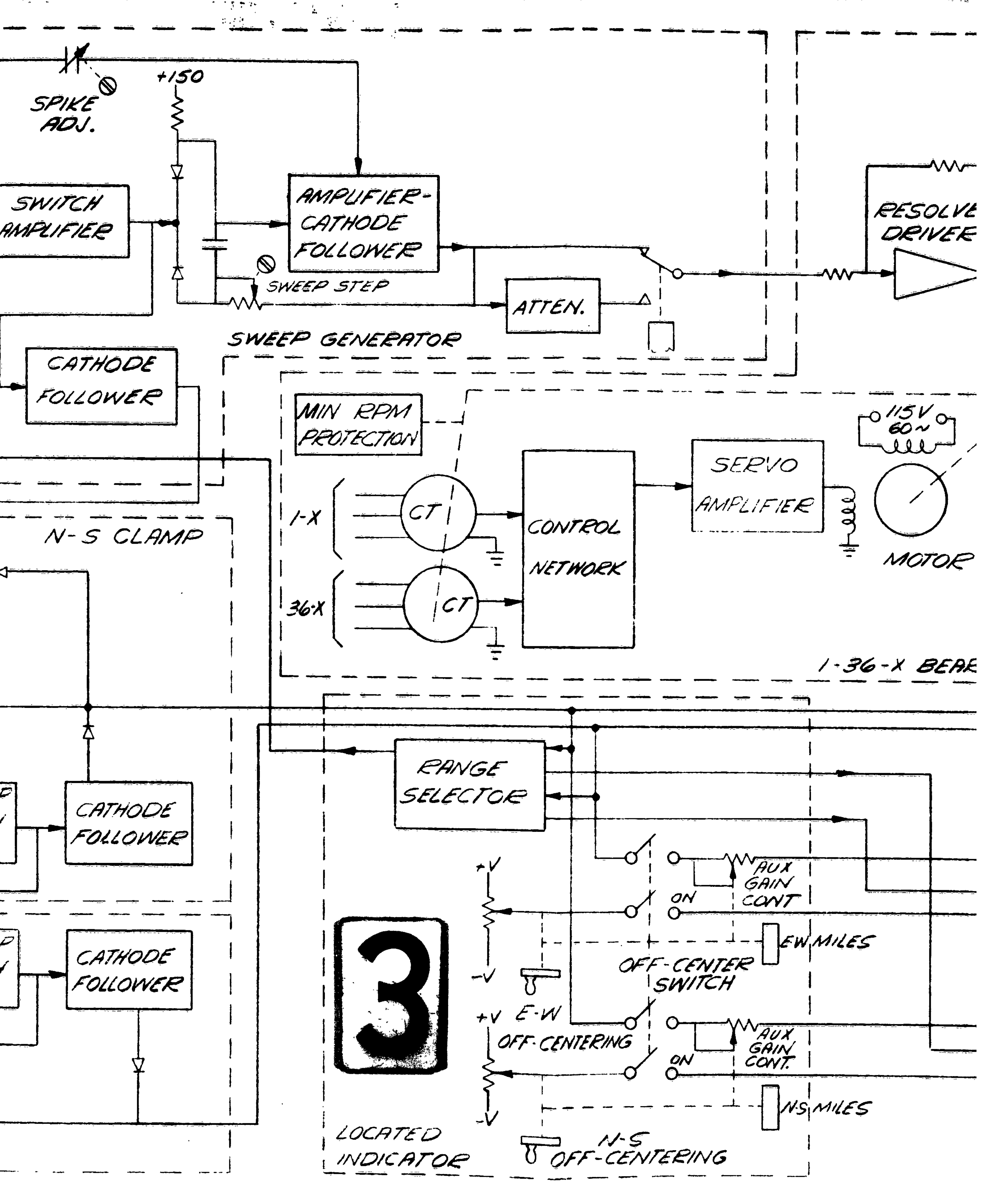
FIG. 4
SCAN MONITOR
BLOCK DIAGRAM


RADAR SYNC PULSE
PULSE AMPLIFIER
TRIGGER GEN.
CATHODE FOLLOWER
TRIGGER & SWEEP GATE GENERATOR
÷ 2
GATE
MARKER OSC
SHAPING CIRCUITS
OFF
ON
RANGE RING SWITCH
-V
RANGE RING SELECT.
RANGE RINGS GENERATOR
RANGE RINGS
SWEEP GATE
BLANKING AMPL
TMA 403X WRITE SIDE
LIMITER
RADAR VIDEO
VIDEO AMPL
MIXER
OUTPUT VIDEO AMPL
H.V. 12KV
MAP VIDEO
MAP VIDEO AMPL
AUTOMATIC INTENSIFIER AMPLIFIER
CATH. FOLL.
D.C. RESTORER
RANGE SELECTOR
-V
SWEEP INTENSITY
+V
VIDEO AMPLIFIER
CLAMP



-150
MAX GATE ADJ
GATE SHARPENER
SWEEP TRIGGER AMPLIFIER
CATHODE FOLLOWER
AMPLIFIER
SWEEP GATE INVERTER
CONTROL AMPLIFIER
THRESH.
DC AMPLIFIER
CATHODE FOLLOWER
-150
70 µS DELAY
STOP
CLAMP GATE GEN.
CATHODE FOLLOWER
UNCLAMP SWITCH TUBE
PULSE AMPLIFIER
START
UNCLAMP SWITCH TUBE
CLAMP REGULATOR
UNCLAMP SWITCH TUBE
UNCLAMP SWITCH TUBE
CLAMP REGULATOR
UNCLAMP SWITCH TUBE
UNCLAMP SWITCH TUBE
E-W CLAMP
2


SPIKE ADJ.
+150
SWITCH AMPLIFIER
AMPLIFIER-CATHODE FOLLOWER
SWEEP STEP
ATTEN.
RESOLVER DRIVER
SWEEP GENERATOR
CATHODE FOLLOWER
MIN RPM PROTECTION
115 V 60 ~
SERVO AMPLIFIER
1-X
CT
CONTROL NETWORK
36-X
CT
MOTOR
N-S CLAMP
1-36-X BEAR
RANGE SELECTOR
CATHODE FOLLOWER
CATHODE FOLLOWER
+V
AUX GAIN CONT
ON
3
EW MILES
-V
OFF-CENTER SWITCH
+V
E-W OFF-CENTERING
AUX GAIN CONT.
ON
NS MILES
-V
LOCATED INDICATOR
N-S OFF-CENTERING

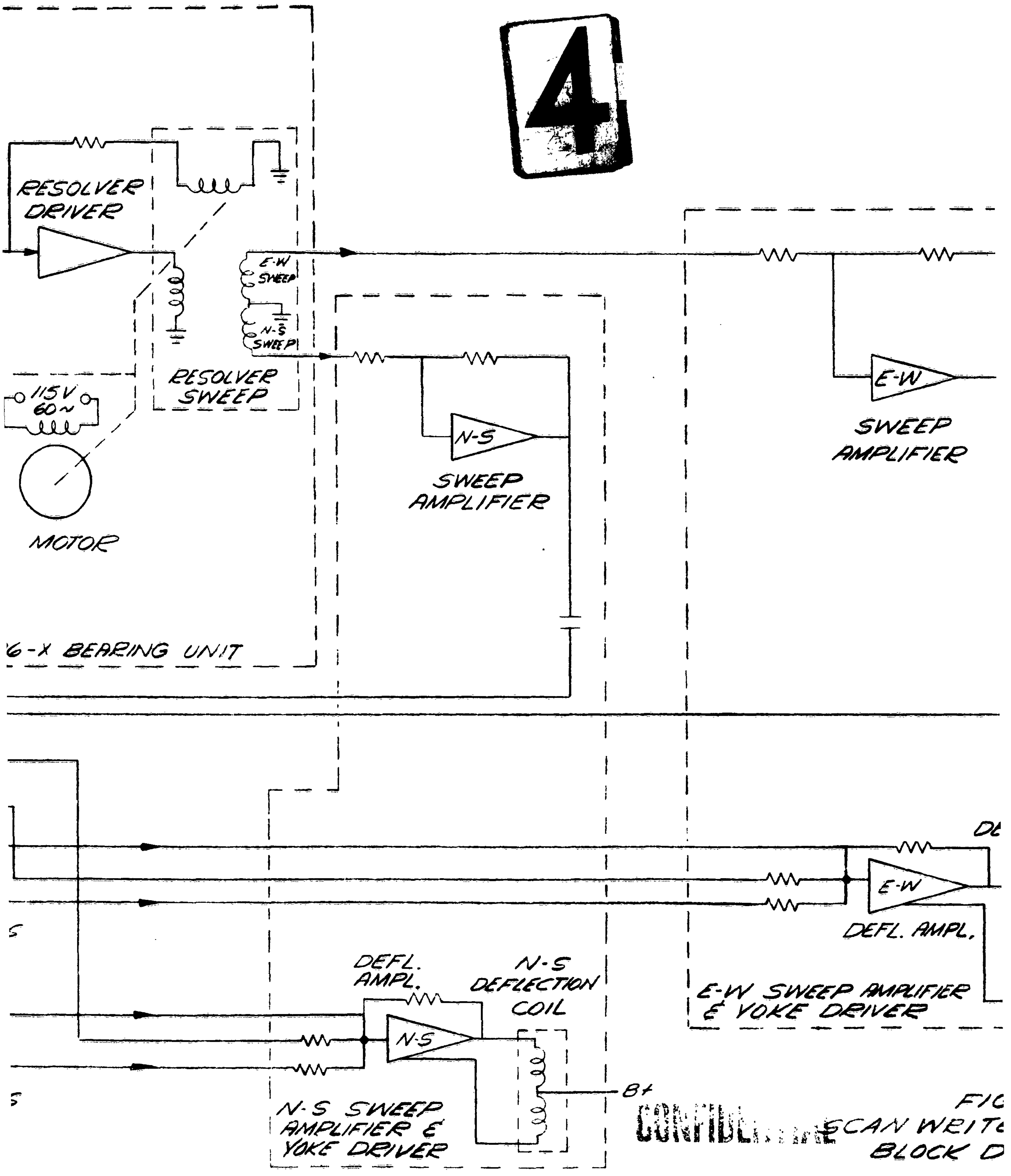
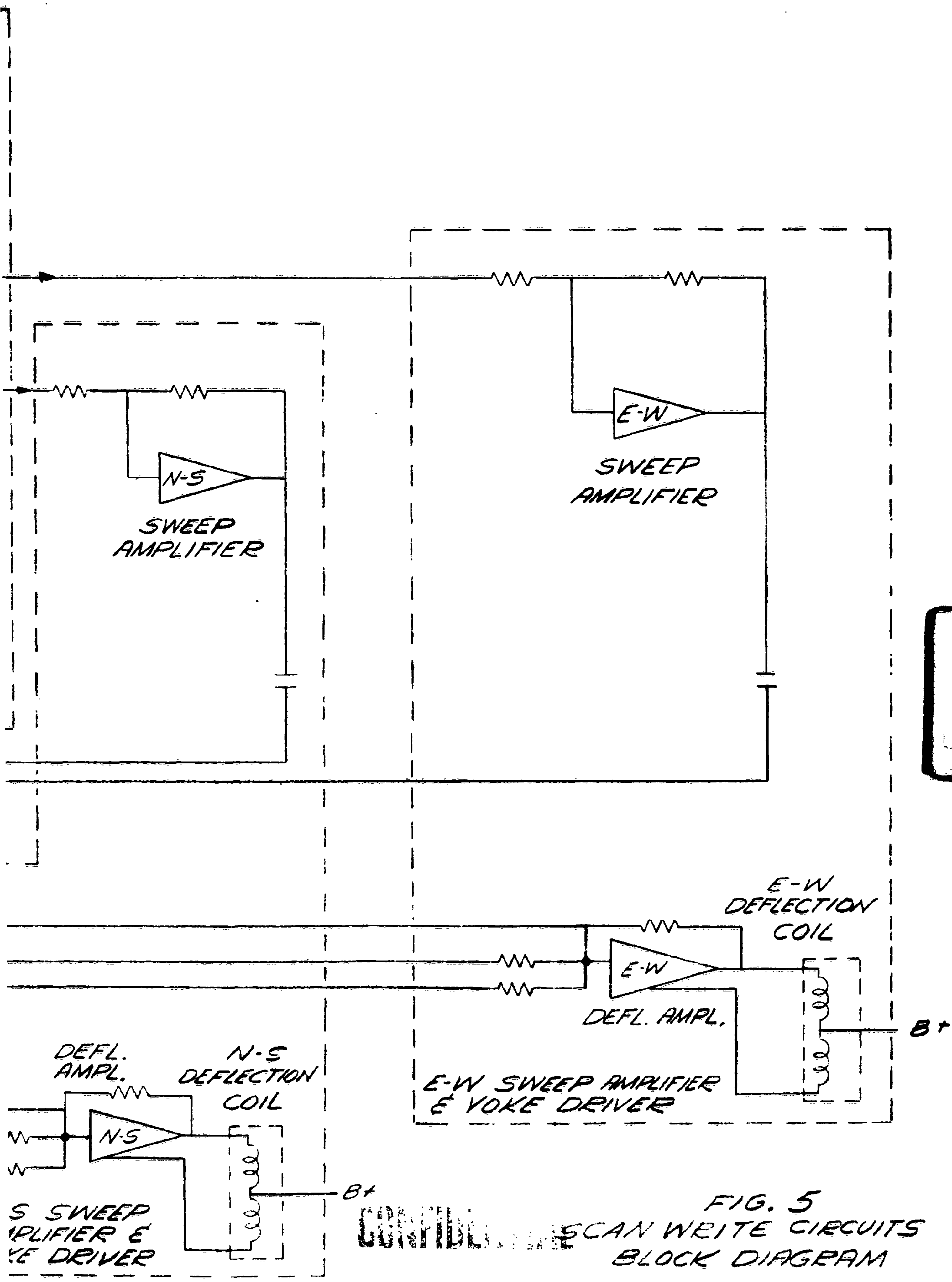
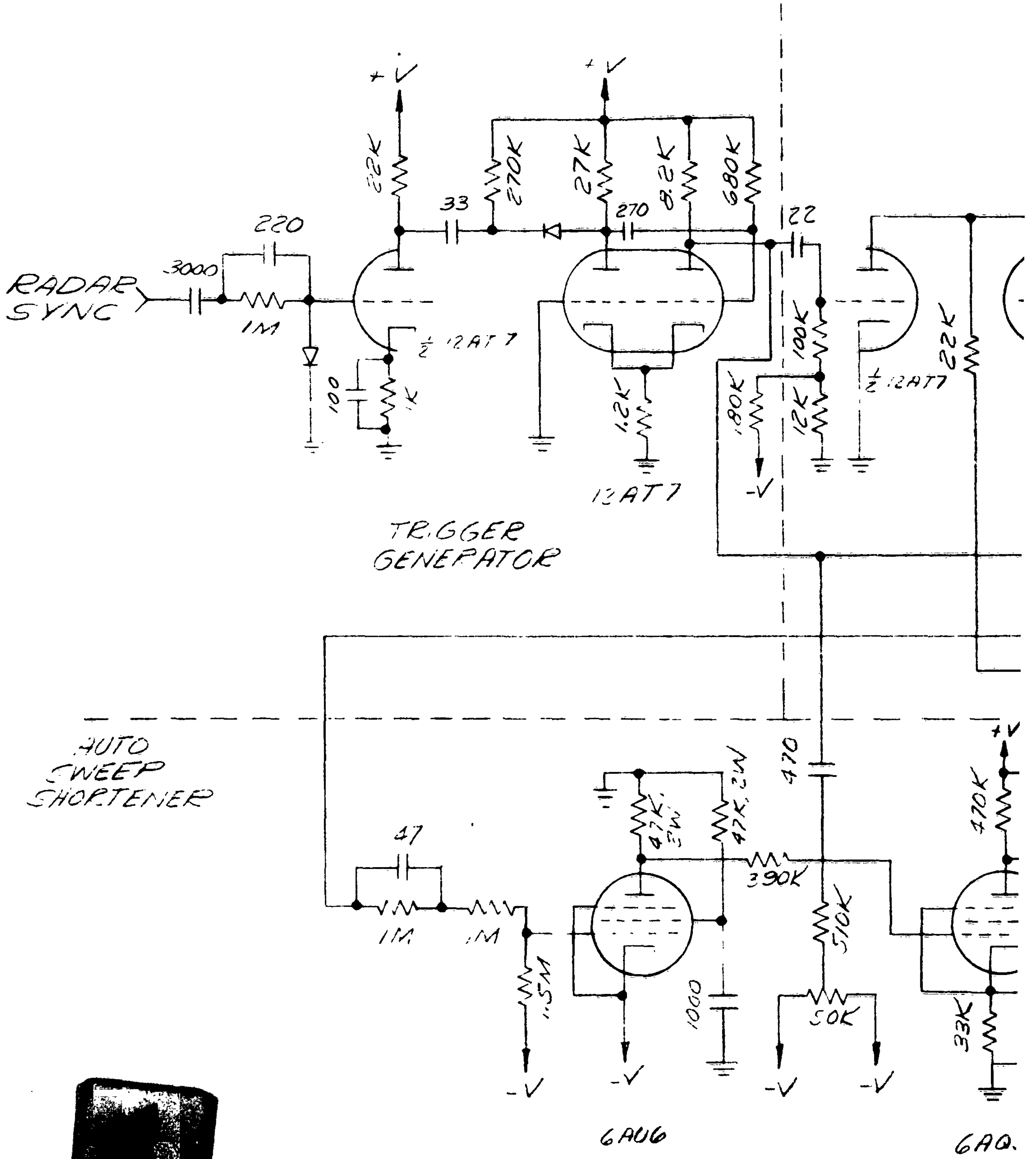


FIG
SCAN WRITE
BLOCK D



5

FIG. 5
SCAN WRITE CIRCUITS
BLOCK DIAGRAM


RADAR SYNC
3000
220
1M
+V
22K
100
1K
½ 12AT7
33
270K
27K
270
8.2K
680K
1.2K
12AT7
TRIGGER GENERATOR
22
100K
180K
12K
-V
½ 12AT7
22K
AUTO SWEEP SHORTENER
47
1M
1M
1.5M
47K, 2W
47K, 2W
1000
6AU6
470
390K
510K
50K
470K
33K
6AQ.

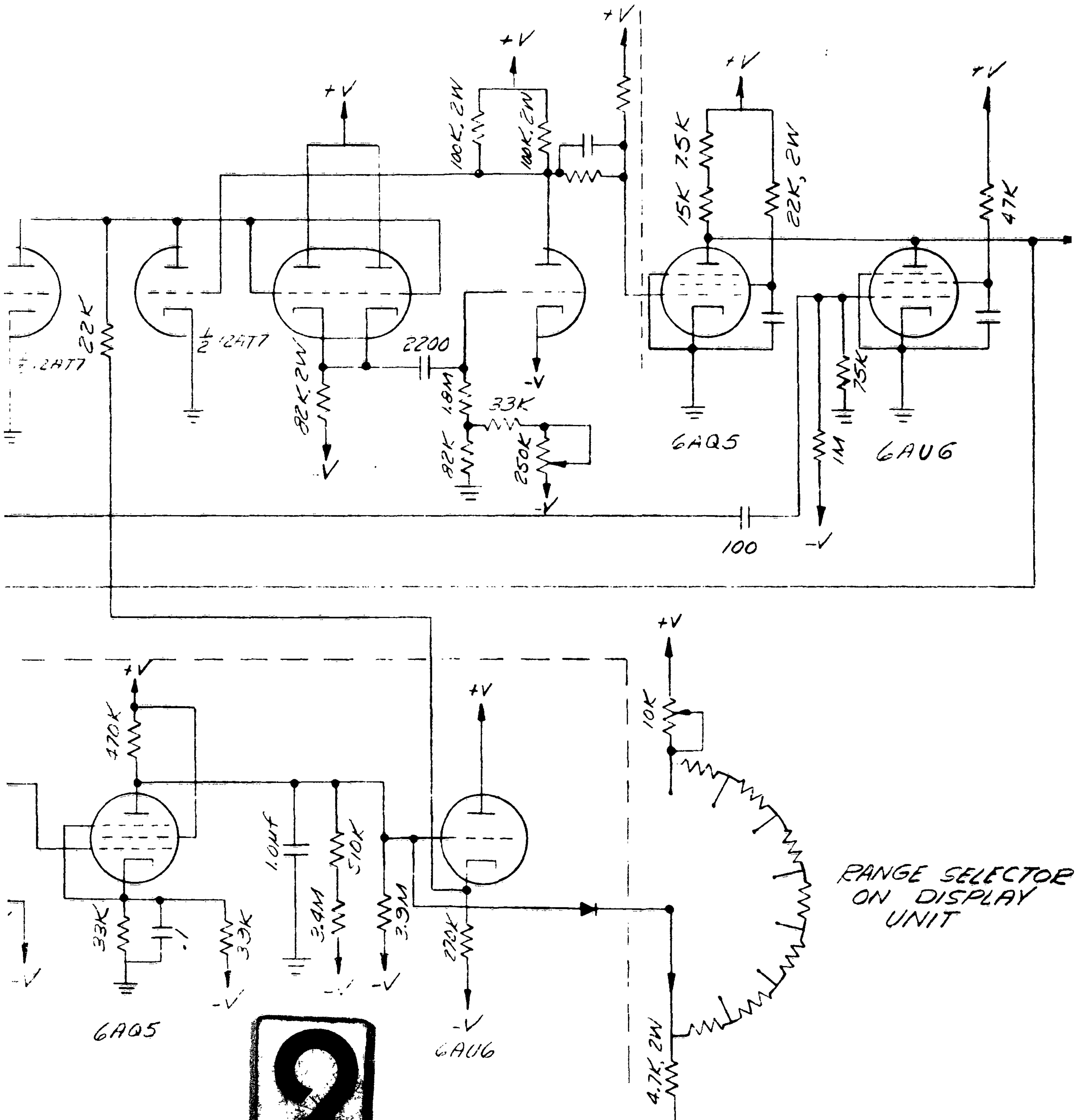


FIG. 6
TRIGGER & C
GENERATO

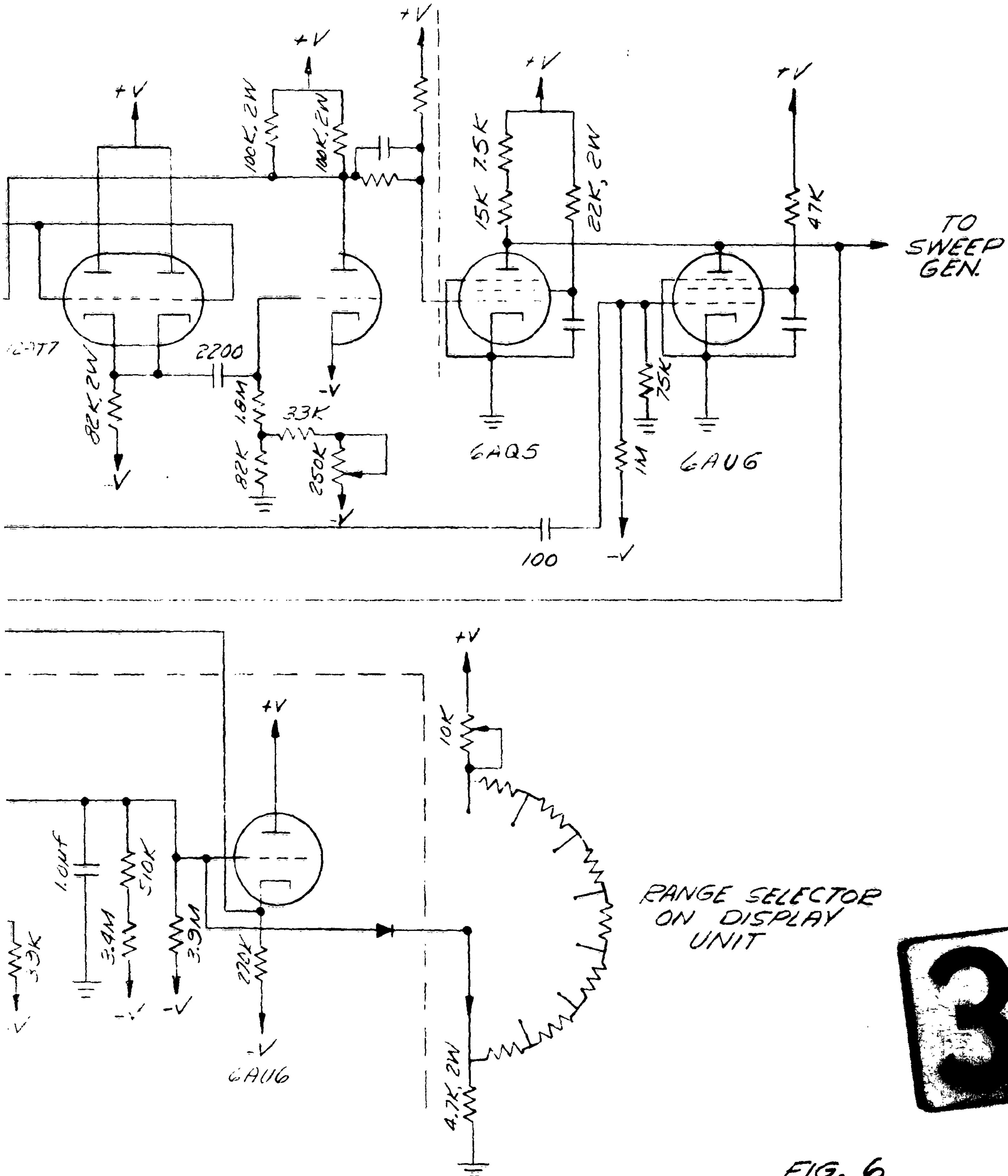
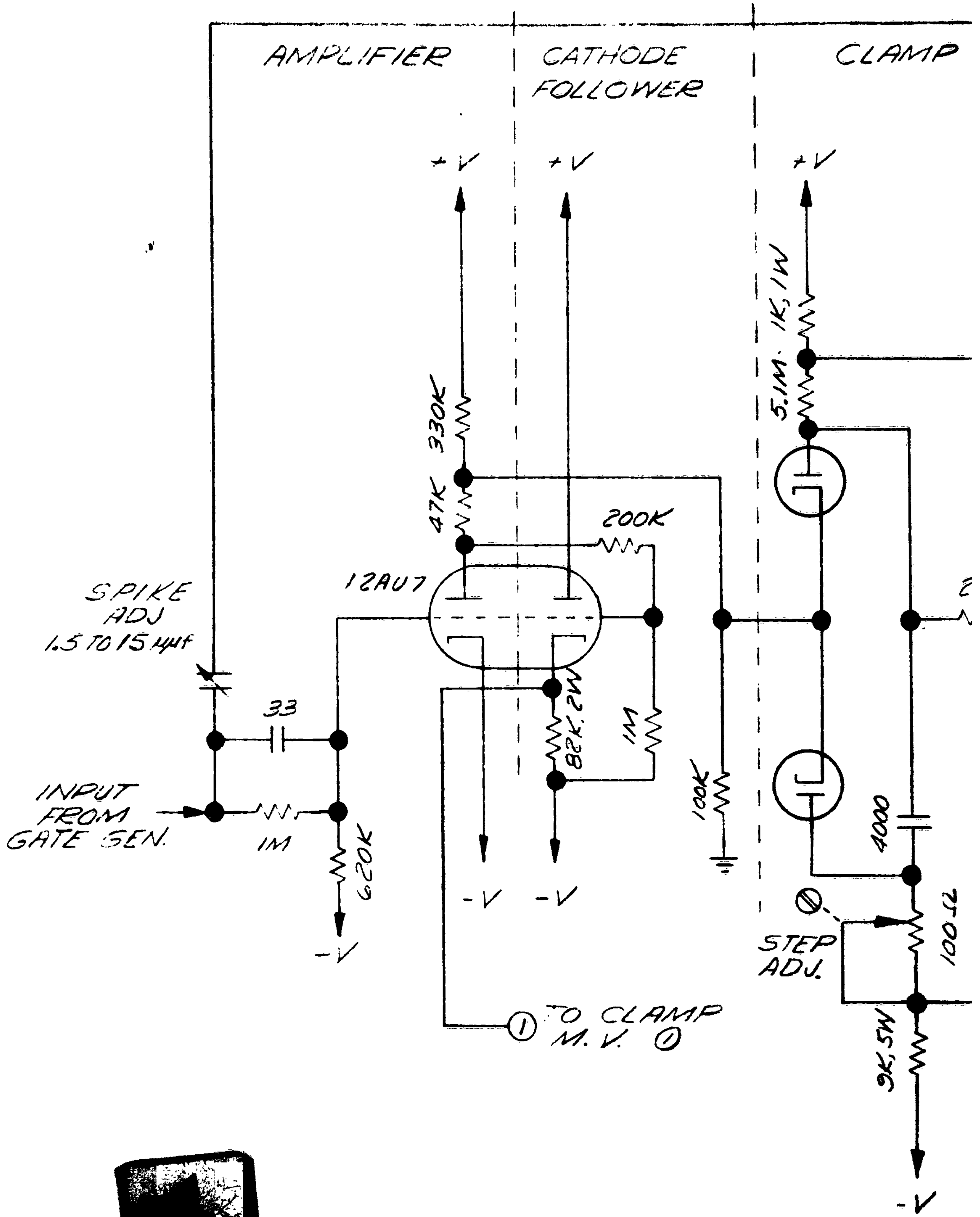
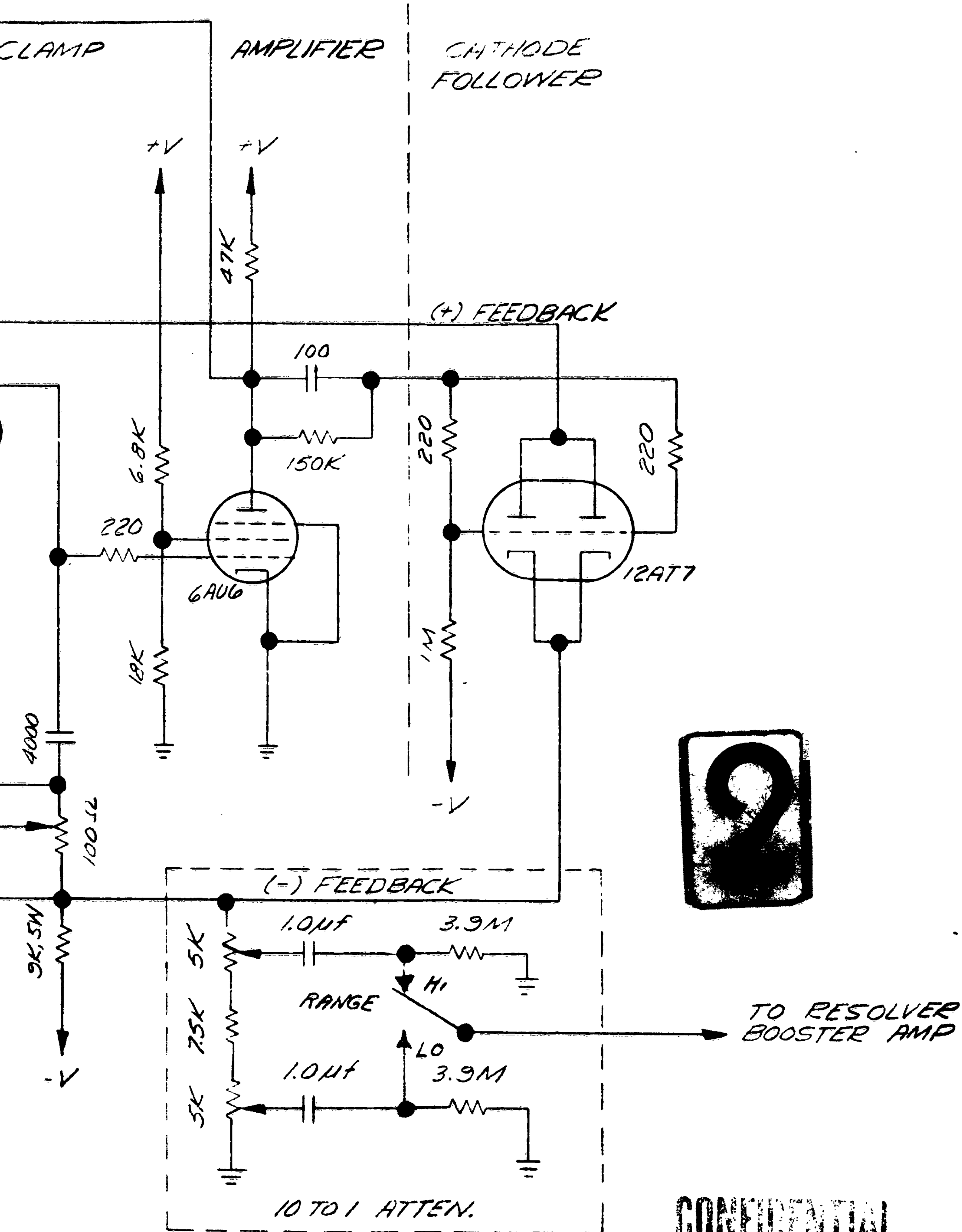


FIG. 6
TRIGGER & GATE GENERATOR

3


AMPLIFIER
CATHODE FOLLOWER
CLAMP
+V
+V
+V
1K, 1W
5.1M
330K
47K
200K
12AU7
SPIKE ADJ 1.5 TO 15 μμf
33
INPUT FROM GATE SEN.
1M
620K
-V
82K, 2W
1M
100K
4000
100Ω
STEP ADJ.
9K, 5W
-V
-V
-V
TO CLAMP M.V. 1



2

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FIG.
SWEEP GE

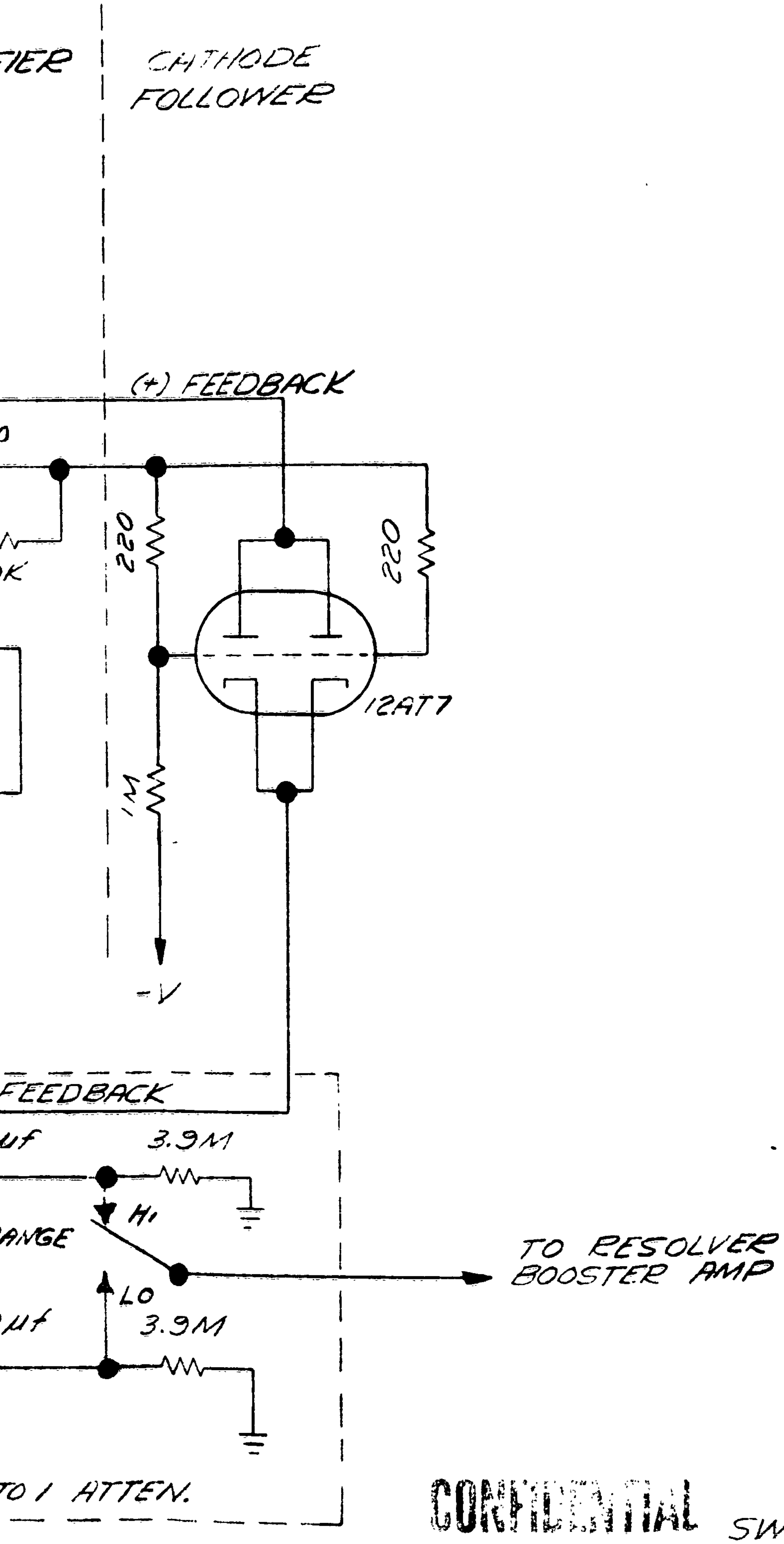

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FIG. 7
SWEEP GENERATOR

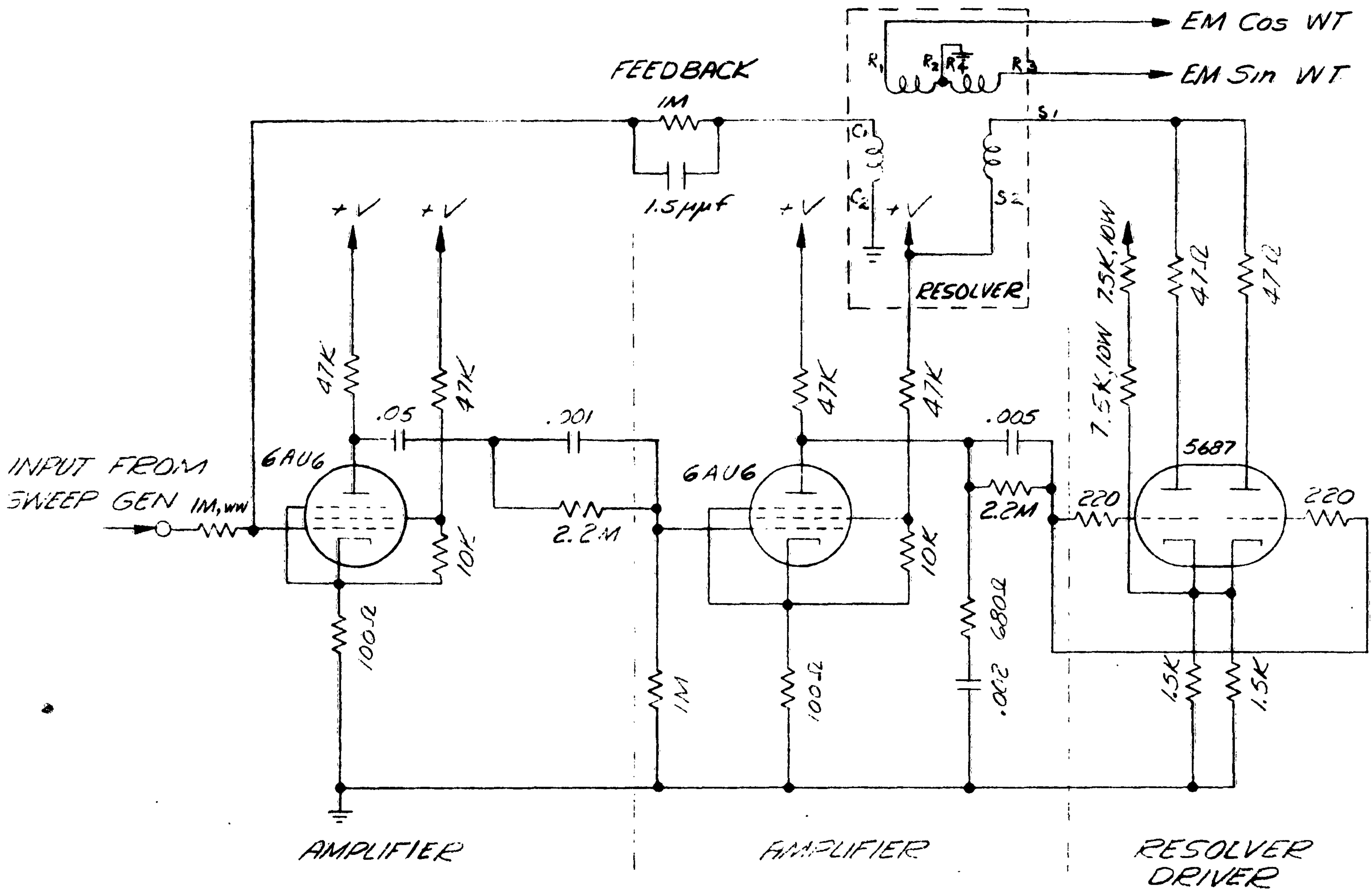


FIG. 8
RESOLVER BOOSTER AMPLIFIER

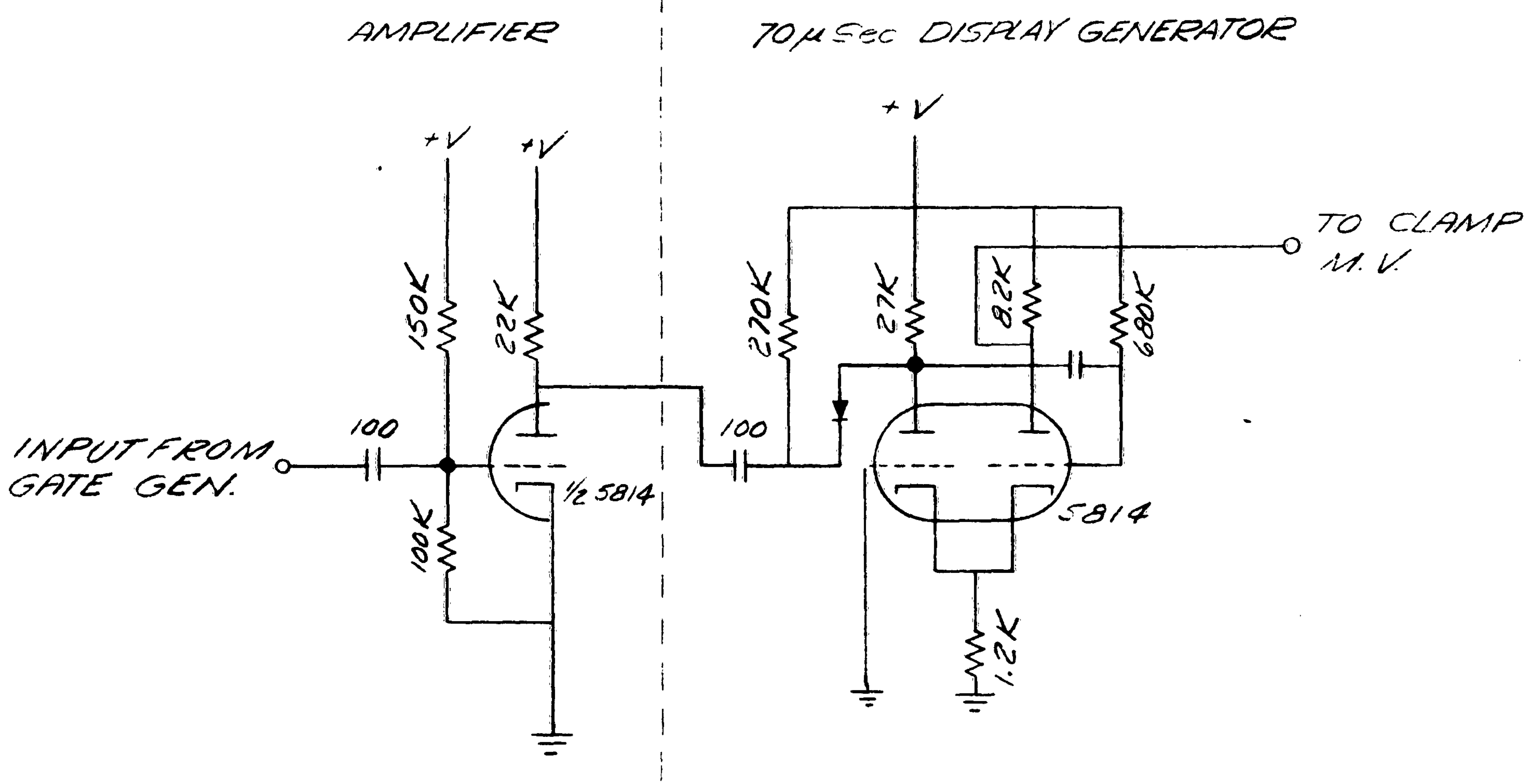
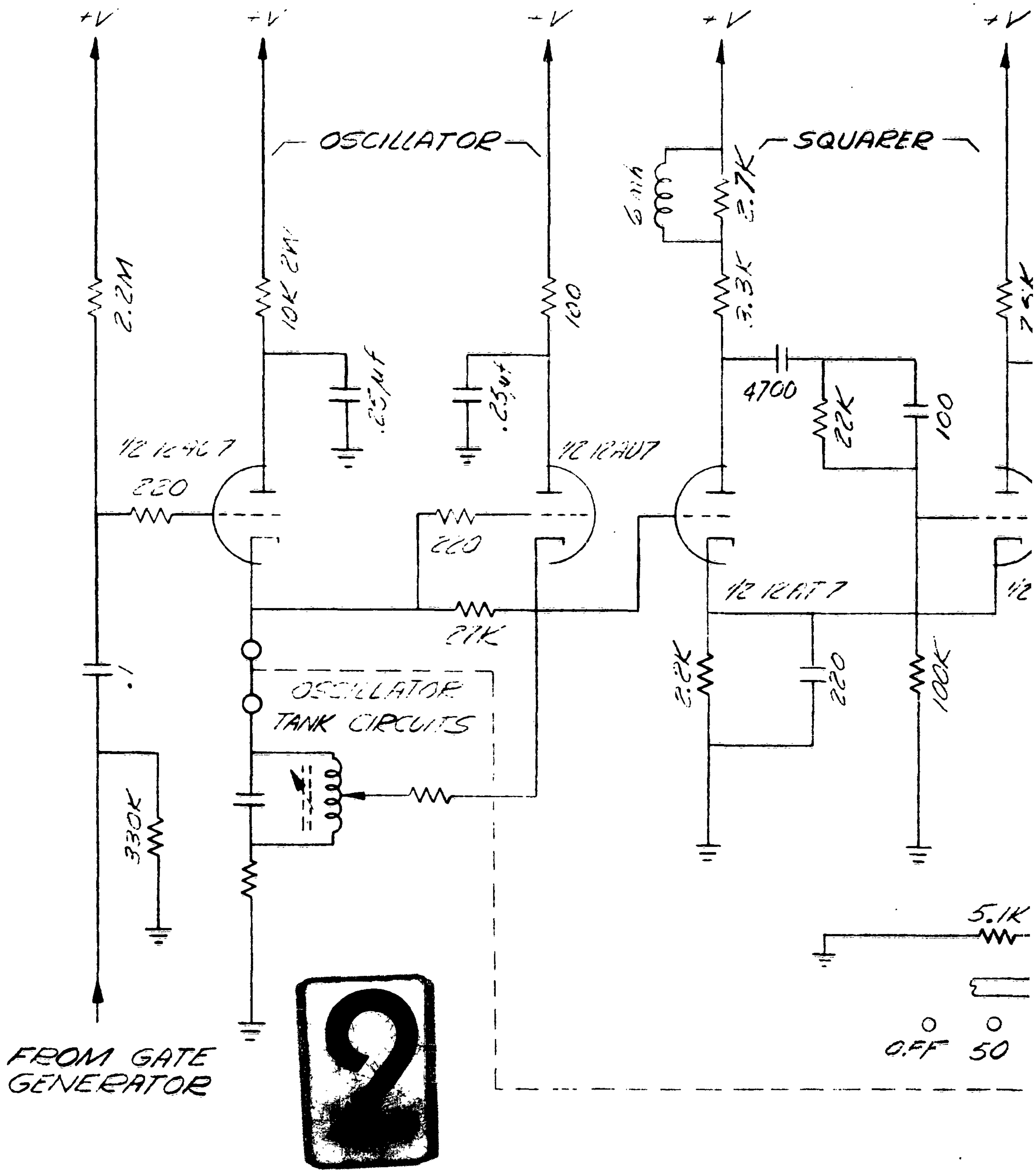


FIG. 9
CLAMP DELAY CIRCUIT

SA 4530-13

S8 15 /14

CONFIDENTIAL



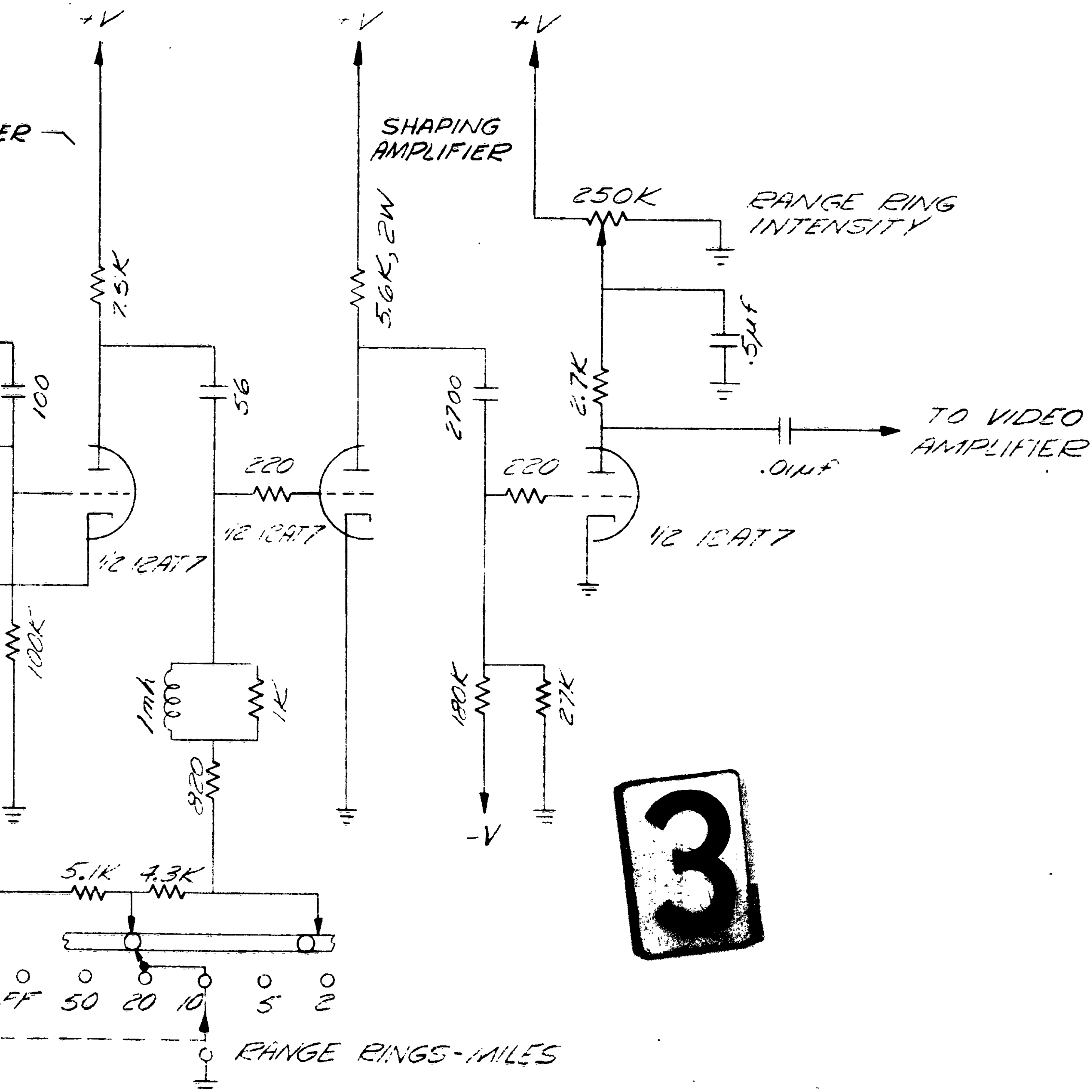


FIG. 10
RANGE RINGS GENER.

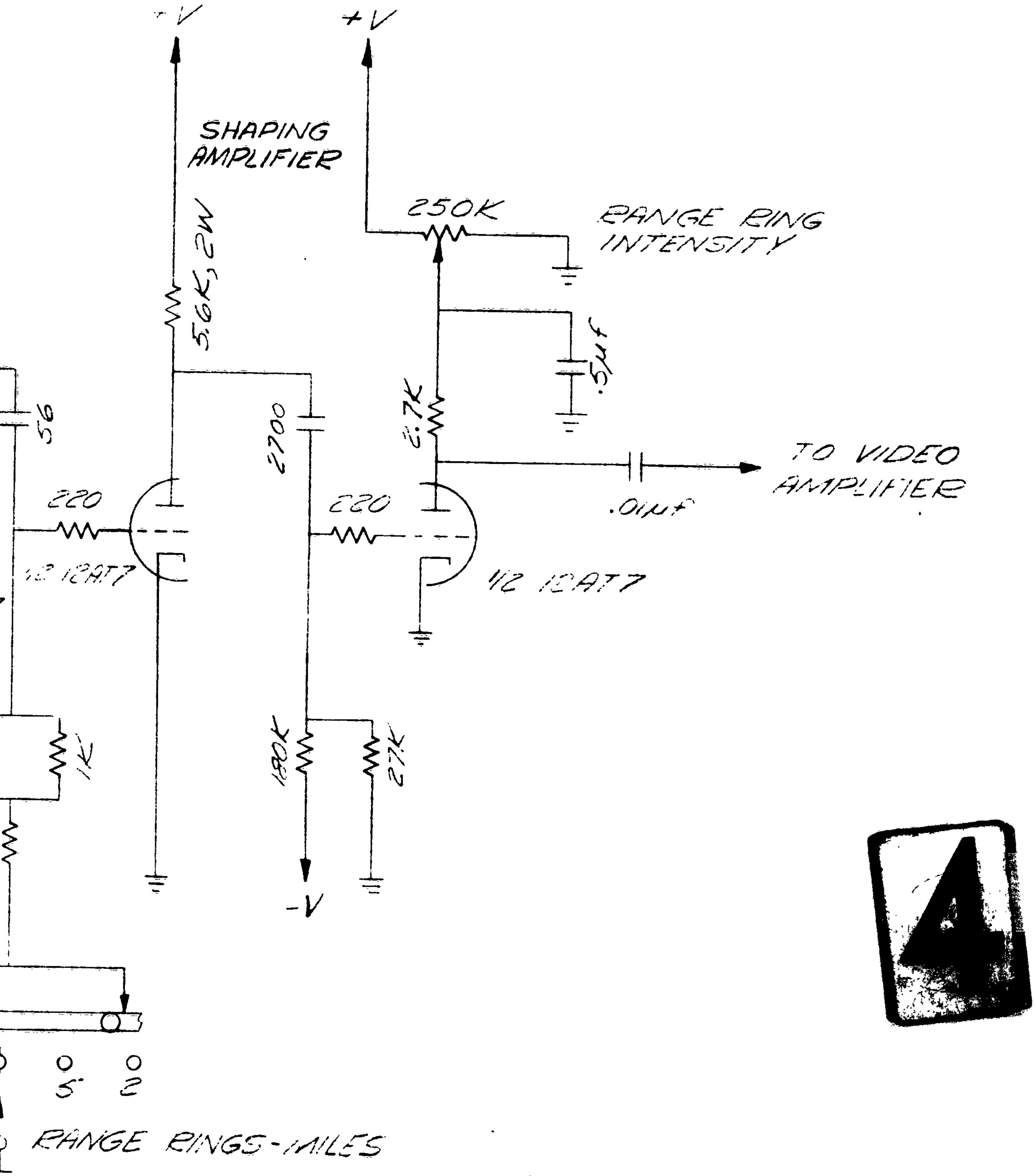


FIG. 10
RANGE RINGS GENERATOR

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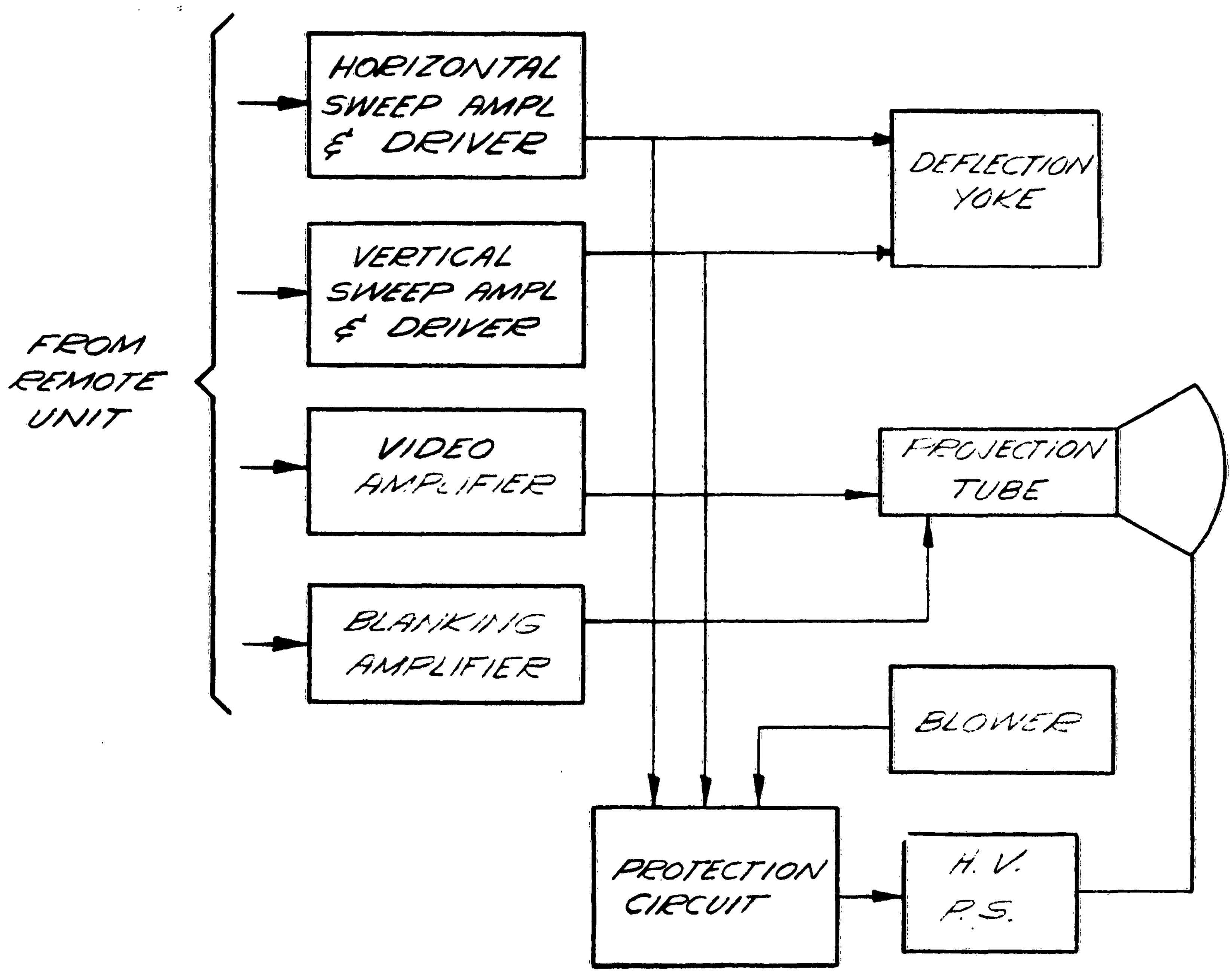

FIG. 11
RATCC DISPLAY INDICATOR
BLOCK DIAGRAM

SA 4530-15

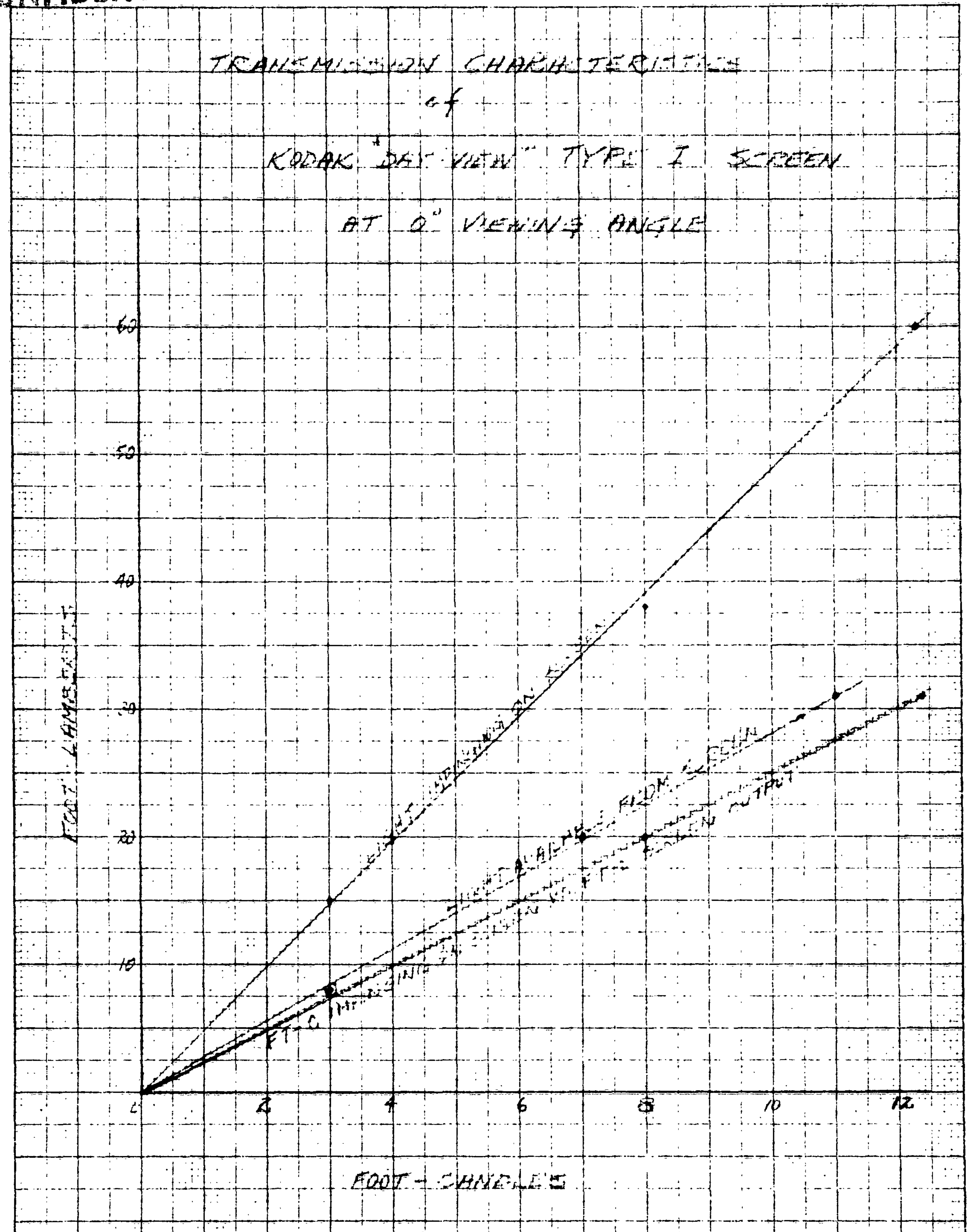

FIG. 12

SA 7573-16

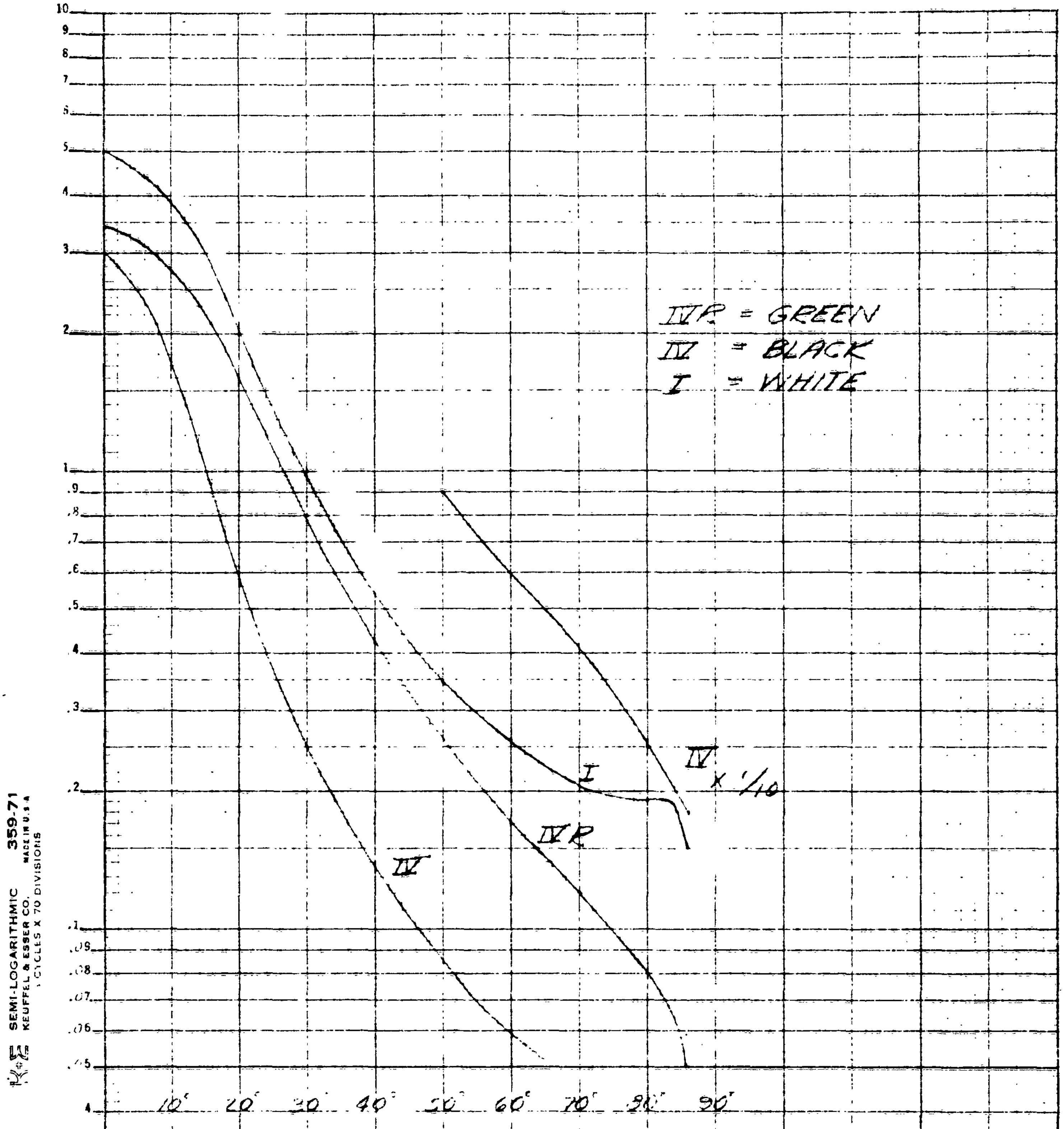

FIG. 13
VIEWING ANGLE VS. RELATIVE BRIGHTNESS OF VIEW SCREENS

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